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AIR FORCE REFUSE-COLLECTION SCHEDULING PROGRAM.(U)  
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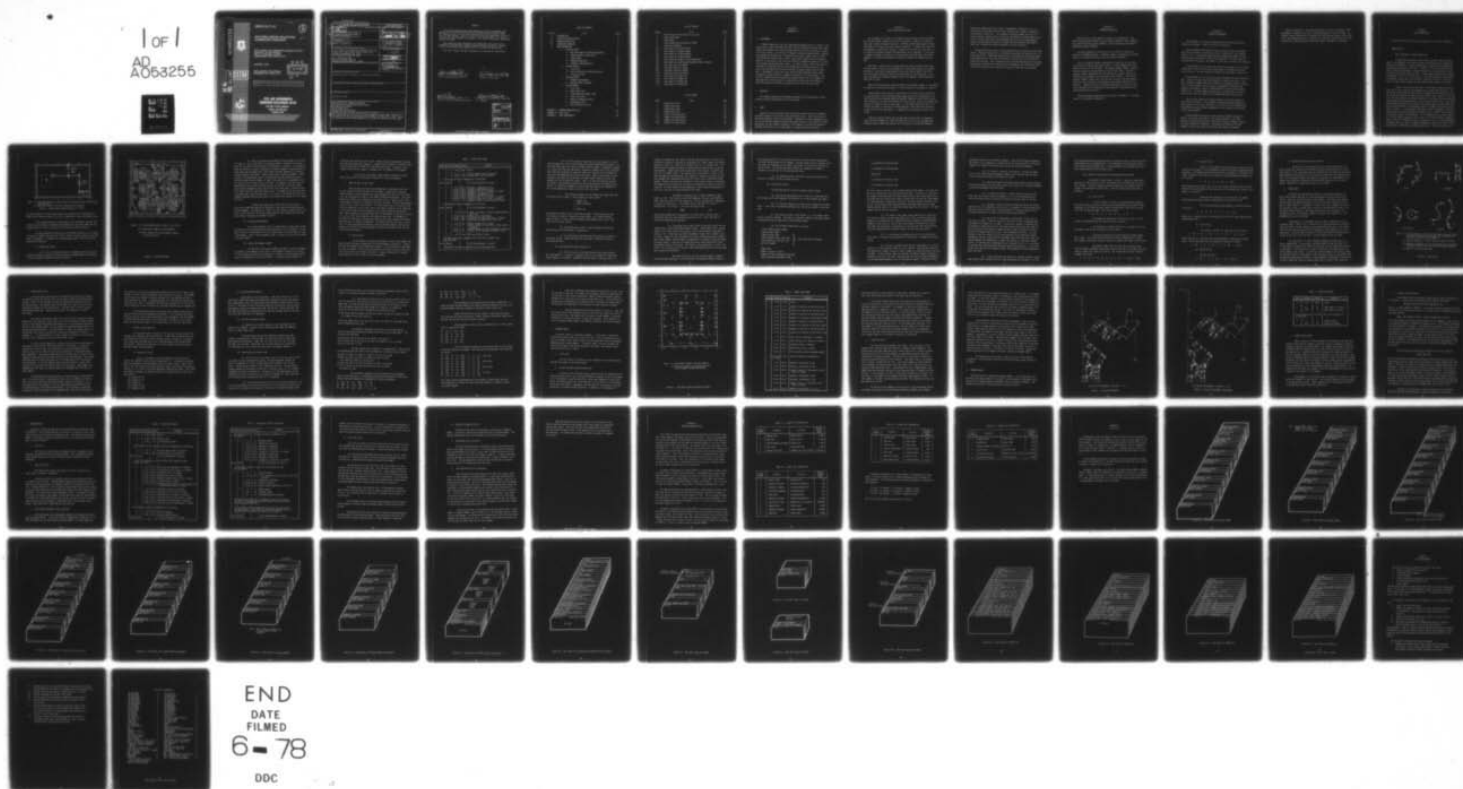
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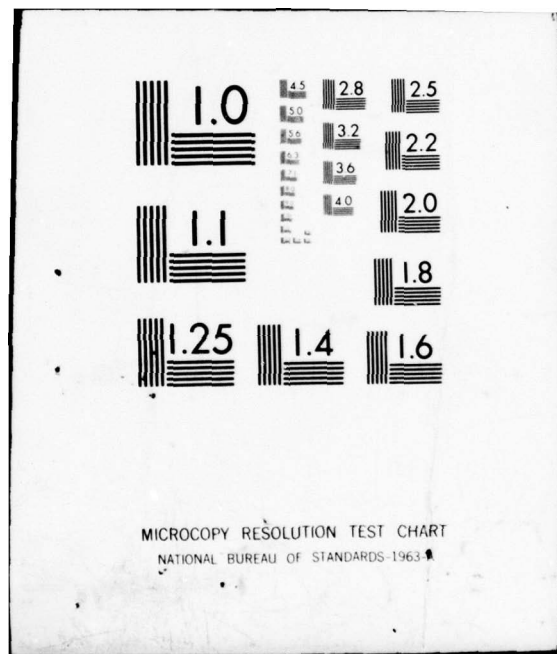
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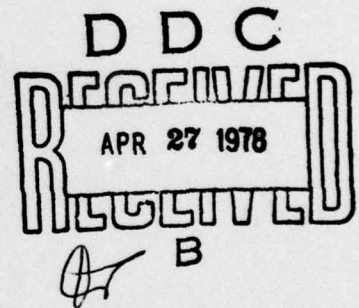
**AIR FORCE REFUSE-COLLECTION  
SCHEDULING PROGRAM**

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FINAL REPORT FOR PERIOD  
DECEMBER 1975-APRIL 1977



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**CIVIL AND ENVIRONMENTAL  
ENGINEERING DEVELOPMENT OFFICE**

(AIR FORCE SYSTEMS COMMAND)

TYNDALL AIR FORCE BASE  
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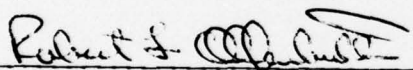
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Data preparation for and use of the four computer programs comprising the Air Force Refuse-Collection Scheduling Program (RCSP) are described. RCSP is used to produce maps and printed schedules for residential refuse collection.		

## PREFACE

This report documents work performed during the period December 1975 through April 1977 by the University of New Mexico under contract F29601-76-C-0015 with the Civil and Environmental Engineering Development Office, Air Force Systems Command, Tyndall Air Force Base, Florida 32403. Mr. Harold J. Iuzzolino was the Principal Investigator. Capt Robert Olfenbuttel managed the program for CEEDO.

This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS it will be available to the general public, including foreign nations.

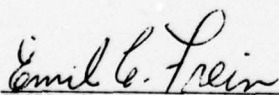
This user's manual has been reviewed and is approved for publication.



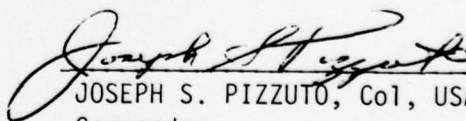
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## TABLE OF CONTENTS

Section	Title	Page
I	INTRODUCTION	1
II	RCSP APPLICATION CRITERIA	2
III	PROGRAM DESCRIPTION	4
IV	SCHEDULING PROCEDURE	5
V	DATA PREPARATION	7
	1. Program RCINPT	7
	a. Map Requirements and Map Preparation	7
	b. Reducing Maps to Data Cards	11
	c. Shape Codes	20
	d. Debugging Map Data	22
	e. Example of Map Reduction	23
	2. Program PHASE2	27
	a. Title Card	27
	b. Collection-Vehicle Description Card	27
	c. Time-Limit Card	30
	3. Program PHASE3	31
	a. Segment Reassignment	34
	b. One-Way Street Problems	35
	4. Program PHASE4	36
	a. Title Card	36
	b. Refuse-Unit Card	36
	c. Street Name and Number Cards	36
	d. Time-Limit Cards	39
	e. Vehicle-Information Cards	40
	f. Map-Bounds Cards	40
	g. Path-Information Cards	40
APPENDIX A:	PROGRAM CHARACTERISTICS	43
APPENDIX B:	DECK SETUP	47
APPENDIX C:	DATA REQUIREMENTS	65

## LIST OF FIGURES

Figure	Title	Page
1	Overall Map Joining Regions A, B, and C	8
2	Loop Housing Map	9
3	Shape Codes	21
4	Loop Housing Map Generated by RCINPT	28
5	Section Assignments	32
B-1	Deck Setup for Program RCINPT	48
B-2	Deck Setup for Program PHASE2	49
B-3	Deck Setup for Program PHASE3	50
B-4	Deck Setup for Program PHASE4	53
B-5	Deck Setup for UPDATE Library Generation	55
B-6	Deck Setup for Generating Executable Binary Programs	56
B-7	Data Deck Setup for RCINPT	57
B-8	Data Deck Setup for PHASE2	58
B-9	Data Deck Setup for PHASE3	58
B-10	Data Deck Setup for PHASE4	59
B-11	Deck Setup for RCINPT Run	60
B-12	Deck Setup for PHASE2 Run	61
B-13	Deck Setup for PHASE3 Run	62
B-14	Deck Setup for PHASE4 Run	63

## LIST OF TABLES

Table	Title	Page
1	RCINPT Data Cards	12
2	PHASE2 Data Cards	29
3	PHASE3 Data Cards	34
4	PHASE4 Data Cards	37
A-1	RCINPT File Description	44
A-2	PHASE2 File Description	44
A-3	PHASE3 File Description	45
A-4	PHASE4 File Description	46

## SECTION I INTRODUCTION

### 1. BACKGROUND

A study conducted at the Civil Engineering Research Facility (CERF) in the period 1973 to 1975 indicated that IBM's Vehicle Scheduling Program (VSP) could reduce both manpower and vehicle mileage required for the collection of refuse on Air Force bases. Use of the VSP, however, presented some problems. Because the program was designed for isolated delivery points rather than a uniform distribution of houses along a street, each street segment had to be approximated by a single point; the resulting schedule produced an unrealistic collection sequence containing many U-turns. Two other serious difficulties were encountered in using the VSP: the path connecting collection points was not given, and considerable effort was required to prepare report quality route maps. Consequently, under Air Force contract CERF developed a more useful residential refuse-collection scheduling program for Air Force bases. The Air Force Refuse-Collection Scheduling Program (RCSP) uses line segments to represent the collection region, indicates the entire path from garage to collection region to landfill, and draws maps of the collection route.

### 2. OBJECTIVE

This manual presents the information needed for the performance of RCSP refuse-collection scheduling for Air Force bases.

### 3. SCOPE

Conditions are given under which RCSP should produce savings in manpower and total mileage for existing refuse-collection routes. Other situations in which RCSP might be useful are described. Procedures for data preparation and for use of the four computer programs that make up RCSP are described in detail. Few details of the internal workings of the programs are given here because a thorough description will be published in a program description manual.

## SECTION II

### RCSP APPLICATION CRITERIA

The intended use of RCSP is to schedule house-to-house refuse collection. For existing routes, reductions of 10 to 20 percent in number of collection trips and in total mileage are typical. Therefore, RCSP should improve scheduling where 10 or more trips are currently required. If fewer than five trips are required, a reduction is unlikely. Where five to nine trips are used, it is difficult to predict whether any improvement can be obtained. In any case, if numbers of houses serviced per trip are poorly balanced under the current schedule, it should be worthwhile to attempt to improve the scheduling with RCSP.

When RCSP is used to set up routes where no routes currently exist, the minimum number of trips will be produced for either house-to-house or dumpster collection. The total mileage should be very near the minimum in the first case and probably within 10 percent of the minimum in the second case. However, the maps and schedules produced by RCSP for dumpster collection may be difficult to read.

RCSP can also be used to study the effect of potential changes in the number or capacity of collection vehicles or in the location of the garage or landfill.

Although RCSP usually does not perform well for dumpster-type collection, it could be useful if the following three conditions exist simultaneously: (1) 10 or more trips are required under the present schedule to service all collection locations, (2) each vehicle makes two trips per day, and (3) the garage and landfill are some 10 miles or more apart. If all these conditions exist, use of RCSP may effect a reduction in mileage through a more efficient selection of the two trips for each vehicle. A reduction in the number of trips is not likely.

There are several reasons why the RCSP does not work well for dumpster-type collection scheduling. When the container is in a lot or driveway that cannot be given a name, the location will be blank on the printed schedule,

making the schedule difficult to use. Furthermore, collection is indicated on the final route maps by broken lines, while travel without collection is indicated by a solid line. If a container location extends less than 1/4 inch on the map, which usually is the case, the broken line may appear to be solid. Finally, the total travel distance may not be the minimum because neither the sectioning algorithm in PHASE2 nor the traversal algorithm in PHASE3 was intended for widely separated collection locations.

Another difficulty occurs if some containers are serviced more often than others. The RCSP assumes that all collection locations are serviced once in a given time period. When some containers are collected more often than others, the program must be rerun with the locations that are not to be serviced deleted from the data. This situation exists at Wright-Patterson Air Force Base, and dumpster collection for that base was consequently not scheduled by RCSP because the extensive time required to change the data was not available.

### SECTION III

#### PROGRAM DESCRIPTION

RCSP consists of four computer programs run sequentially: the data-checking program (RCINPT), the section-assignment program (PHASE2), the route-traversing program (PHASE3), and the route-map and schedule-generating program (PHASE4).

The four programs are written to run on a SCOPE 3.4 Operating System on a CDC6600 computer. Graphical output is produced by a Calcomp drum or a flatbed plotter with a 30-inch minimum dimension.

The first program, RCINPT, processes map input data and verifies the accuracy of the map description cards. It also computes the total amount of refuse to be collected. The second program, PHASE2, sections the map into pieces corresponding to single truck loads. The third program, PHASE3, determines for each section two traversal paths, one starting at the garage and one starting at the landfill. The fourth program, PHASE4, selects two trips per day for each collection vehicle, the first trip starting at the garage and the second starting at the landfill. PHASE4 also prints a schedule describing all travel for each trip, intersection by intersection, and generates a Calcomp plot tape containing maps of the trips.

Detailed program characteristics are given in Appendix A. The deck setup is illustrated in Appendix B.

## SECTION IV SCHEDULING PROCEDURE

The following is an overall description of the refuse-collection scheduling procedure. Details are given in Section V.

Data associated with the map of the collection region are punched onto cards according to instructions given in Section V-1, and program RCINPT is run. The printed output and maps produced by RCINPT are then used to check the accuracy of most of the map data. The data cards are corrected where necessary, and RCINPT is rerun until no errors are apparent.

Program PHASE4 can be used at this point to draw maps of the original routes and to find or verify the maximum number of households serviced by one vehicle. The data required by PHASE4 are described in Section V-4.

Program PHASE2 is run once using vehicle-capacity and time-restriction data. Section V-2 describes the procedure for punching the data. The maps produced by PHASE2 show which streets are assigned to each collection trip. If minor changes to these section assignments are desired, the changes are punched as input to program PHASE3 in the form described in Section V-3. If major changes are desired, the time limits or vehicle-capacity data used for PHASE2 can be changed and PHASE2 can be rerun.

The only data required for program PHASE3 are the node numbers of the garage and landfill. Since PHASE3 can reassign street segments to other sections on its own initiative, it is best to run the program once and examine its output before attempting to run it with user-initiated section reassignments.

Program PHASE4 displays the route traversal schedule produced by PHASE3. The nature and extent of any desired changes in the final output will determine the point in the total four-part program at which the input data must be modified. The programs affected by the data changes are then rerun until the desired route maps are produced.

Human intervention in the scheduling process is likely to produce little improvement: probably less than a 1-percent reduction in total mileage. At present, human intervention is necessary only when one-way streets cause either of the two problems described in Section V-3, and these problems may have been solved by the time the program description manual for PHASE3 is completed.

## SECTION V

### DATA PREPARATION

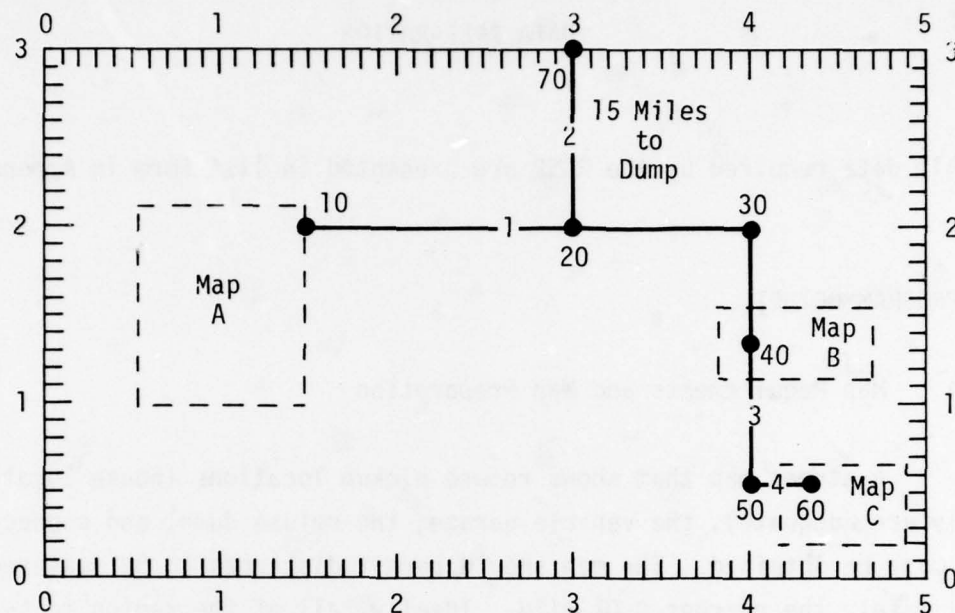
All data required by the RCSP are presented in list form in Appendix C.

#### 1. PROGRAM RCINPT

##### a. Map Requirements and Map Preparation

A street map that shows refuse pickup locations (house locations usually are adequate), the vehicle garage, the refuse dump, and connecting roads must be obtained. The map should permit distances to be measured to approximately the nearest 0.01 mile. Ideally, all of the region to be covered in the refuse-collection scheduling should be on one map with a scale of between 200 and 800 feet per inch. Street lengths could then be measured conveniently in 1/8- or 1/10-inch units. Since the ideal map cannot always be obtained, several maps with different scales may be used if an overall map or accurate sketch showing how the separate maps connect is available.

Figure 1 indicates how the maps of three widely separated housing areas (A, B, and C) may be tied together by an overall map or sketch. The map scales for the housing areas should be between 800 and 200 feet per inch, but the overall map may be drawn to a much higher scale, possibly 1 mile per inch. All intersections and street endpoints on all maps to be used are given unique numbers called node numbers, as will be described further. One intersection from each map must be shown on the overall map; note that node 10 of map A, node 40 of map B, and node 60 of map C all appear on the overall map shown in Figure 1. A rectangular coordinate system is appended to each map. The coordinate system unit should be between 1 and 5 inches long, the actual value being a matter of convenience. If a gridded overlay is used, either 2, 5, or 10 divisions, whichever falls in the 1- to 5-inch interval, should be used as one unit. Otherwise, the unit should be 2-1/2 or 2 inches depending on whether the ruler used is graded in eighths or tenths of an inch. (Each map may have a different coordinate-system scale.) The user may then tie



Note: (1) Two-digit numbers are node numbers indicating street intersections and endpoints.  
 (2) One-digit numbers are street identification numbers.

Figure 1. Overall Map Joining Regions A, B, and C

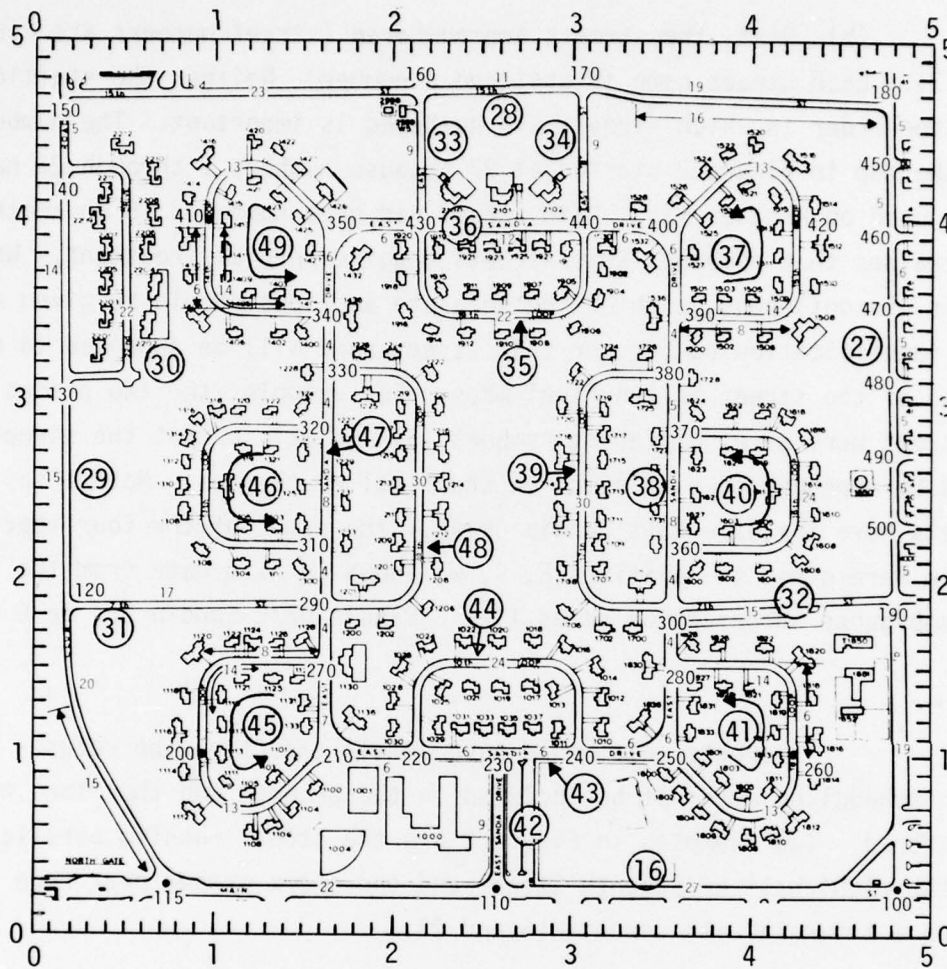
the maps together in the map input program by specifying the coordinates of nodes 10, 40, and 60 on maps A, B, and C, respectively, and on the overall map.

If the vehicle garage or refuse dump is not included on any map, the distance to the garage or dump should be indicated at the point where the collection vehicle is likely to enter or leave the area shown on the map.

The map preparation process will be described in detail at this point. In practice, however, the user will find it simpler to mark the map as the data cards are prepared. In reading the following explanation, refer to the loop housing map (Figure 2).

#### (1) Numbering Streets

(a) First, a coordinate system is appended to the map. (Satisfactory alternatives would be to trace the map on gridded paper or to overlay it with a gridded, transparent sheet of plastic.)



- Notes: (1) Street-identification numbers are circled.
- (2) Three-digit numbers are node numbers.
- (3) Small numbers are street-segment lengths, in 0.01-mile units.

Figure 2. Loop Housing Map

(b) Next, the streets are numbered (street numbers are circled in Figure 2). Each street name is assigned a number. Neither the starting point nor the order in which streets are numbered is important. The numbering shown on the map in Figure 2 started at 27 because numbers 1 through 26 had already been used on another map. Main Street had been numbered 16 on another map and retained that number. Some streets require special treatment. Where a street is discontinuous, each of the separate sections should be given a different identification number, or that street name will be appended to only one section of the street on the final maps. For example, the two pieces of Seventh Street were given different numbers (31 and 32) so that the street name would be appended to each piece on the final route maps. Note also that five streets have the name East Sandia Drive. The names of the four that form a rectangle were given the suffixes E, S, W, and N to eliminate from the final schedule ambiguous intersection names like E Sandia Dr/E Sandia Dr, or E Sandia Dr/7th St.

Streets that would have little effect on the refuse-collection scheduling need not be included in the program and therefore need not be numbered. Two examples in Figure 2 are the street running parallel and close to the right half of Seventh Street and the short street near node 100, which forms a triangle with streets 16 and 27.

## (2) Assigning Node Numbers

All street endpoints and all intersections, except those formed by either of the two unused streets mentioned above, must be numbered. If the point at which a street bends is not an intersection, it usually does not need a node number. Most of the rectangular loops in Figure 2 have only two corners with node numbers.

## (3) Indicating Segment Lengths

The portion of any street between two nodes is called a segment. The length of the segment can be given to the program in either of two ways: (1) The length on the map can be measured in inches, or (2) the actual street length in hundredths of a mile can be used. If actual street lengths are

available they should be used; if not, lengths should be measured on the map. For the loop housing map (Figure 2), lengths were available in 0.01-mile units from previous work with IBM's VSP, and these were used. In Figure 2, the length of each street segment is appended near the middle of the segment.

In some cases, additional length numbers having to do with shape codes, which are discussed in subsection c, must be appended.

#### b. Reducing Maps to Data Cards

When the maps are reduced to punched cards, additional data that are not usually found on the maps will be needed: speed limits, one-way street locations, refuse quantity per house accumulated since the last collection, and the number of sides of the street collected on one pass. The refuse quantity per house can be measured in any type of unit: pounds, cubic feet, truck-capacity fraction, or number of families serviced. The unit used depends on what kinds of data are available. If refuse quantities at collection locations are measured in cubic feet, and if the vehicle capacity can be expressed in cubic feet, then the refuse quantity units used by RCSP should be cubic feet. More commonly the available data will be the number of families serviced by a trip, so the refuse quantity unit would be families. For example, on Kirtland Air Force Base a 16-cubic-yard vehicle can service about 220 families with four days of refuse accumulation. The refuse quantity per house is therefore 1 in the map-processing program; in the sectioning program, the vehicle capacity will be 220, the maximum number of families serviced on one trip for existing Kirtland routes.

#### (1) Data Records

In this manual, the word record means all data cards between two end-of-record indicators (cards with 7-8-9 multipunched in column 1). Table 1 outlines the content of the RCINPT data records. The limitations on the number of cards in records 1 and 2 and on the number of strings in records after record 2 result from core storage allotments. Program termination or improper functioning will result if the limits are exceeded.

TABLE 1. RCINPT DATA CARDS

Record	Card	Columns	Format	Contents
1	1	1-80	8A10	Title
	2	1-5 11-60	I5 5A10	Street number (right justified) Street name (left justified)
The above card may be repeated up to 300 times.				
End of Record				7-8-9 multipunched in column 1.
2	1	1-10	F10.0	Minimum x coordinate of map
		11-20	F10.0	Maximum x coordinate of map
		21-30	F10.0	Length of map in x direction, in inches
		31-40	F10.0	Minimum y coordinate of map
		41-50	F10.0	Maximum y coordinate of map
		51-60	F10.0	Length of map in y direction, in inches
		61-70	F10.0	Height of drum plot strips, in inches
		71-72	I2	Sequence number of the coordinate system
The above card may be repeated up to 10 times.				
End of Record				7-8-9 multipunched in column 1.
3	1	1-10	F10.6	Length, in inches, of street length measurement unit
		11-20	F10.6	Map scale, in feet/inches
		21-30	F10.6	Length of map coordinate unit, in inches
		31-40	A10	Coordinate use mode (left justified)
	2	1-5	F5.0	Default speed limit, in mph
		6-10	I5	Default number of directions streets can be traveled
		11-15	I5	Default number of sides collected on one pass
		16-20	F5.0	Default refuse quantity adjustment factor
	3	1-80	Free	Map description strings
The above card may be repeated until 500 street segments have been described.				
End of Record				7-8-9 multipunched in column 1.
The above record may be repeated for each additional map.				

(a) The first record of data input to the program is a title card followed by a list of street names and street identification numbers. On each card after the title card, the identification number is punched in columns 1-5, right justified, and the name is punched in columns 11-60, left justified. The cards must be placed in numerical order, but need not be in alphabetical order, and the numbering need not be continuous. Where street names are not available, the names may be omitted, but where these streets are used, the schedule will be printed with blanks. Note: For the discontinuous streets discussed in the preceding subsection, the street name must be repeated with each of its identifying numbers to ensure that the name will be appended to all of the appropriate street sections on the final maps.

The following examples of card images were generated from the overall map in Figure 1, which shows only four streets:

- 1 SUNSET HWY
- 2 ROAD TO LANDFILL
- 3
- 4 HALLET RD

The names for streets 2 and 3 could not be found. A description was used for a name for street 2; street 3 was left blank. All streets actually shown on maps A, B, and C would be numbered and added to this list to complete the first data record.

(b) The second data record is used to debug the remaining records and will be described in subsection d.

(c) The third data record describes the overall map and its coordinate system. (Additional maps are described in additional records, one record per map.)

## (2) Map Description Record (Record 3)

(a) The first card in each record describing a map contains this information: in columns 1 through 10 the unit (in inches) for measuring street lengths; in columns 11 through 20 the map scale in feet per inch; in

columns 21 through 30, the length of the map coordinate unit in inches; and starting in column 31, the mode of coordinate use. Street lengths are usually measured in units of 1 inch, 0.125 (1/8th) inch, or 0.1 (1/10th) inch. The latter two are convenient because no decimal points need be used on the map descriptions. Lengths could also be measured in millimeters, in which case the unit is 0.03937 (inch). The smallest unit, millimeters, results in the most accurate map representation, but eighths or tenths of an inch will produce adequate map representations with less effort and are therefore recommended. Tenths of an inch are preferable if this type of ruler is available. The program uses the map scale to convert the length from inches to miles internally. If street lengths can be measured in units precisely equivalent to 0.01 mile, the unit of length should be left blank.

The mode of coordinate use is either AVERAGE (or AVG), FIRST, or LAST. LAST should be used for debugging the maps, and AVERAGE or FIRST should be used for final scheduling. (A full explanation of debugging is given in subsection d.) The format used to read the first card is (3F10.6,A10). For Figure 1, the first card would read:

.1            10560.            .1            LAST

(The street lengths will be measured in 0.1-inch units, the map scale is 10,560 feet per inch, the coordinate system unit is 1 inch, and LAST is used while debugging the map data.)

(b) The second card in each record of map data allows for the redefinition of four established default values: 15-mph speed limit, two-way streets, two sides collected on one pass, and a refuse-quantity adjustment factor of 1.0. These four positional parameters--speed limit, number of ways of travel, number of sides collected on one pass, and refuse-quantity adjustment factor (RQAF)--are described in paragraphs (h) through (k) and are needed for each street; if they are not specified on the street description cards, the default values will be used. The format of the second card is (F5.0, 2I5, F5.0). This card may be left blank if the established defaults are to be used, but it must not be omitted.

The speed limits for all four streets shown in Figure 1 will be 45 mph; therefore, it will be easier to change the default value on

the second card from 15 to 45 than to specify 45 on each street description. The other defaults need not be changed: the four streets are all two-way, and the other two parameters do not apply since there is no refuse collection on these streets. The second card would contain 45. somewhere in columns 1 through 5, and the rest of the card would be blank.

(c) The remaining cards in record 3 describe the map and are discussed in detail in the following section.

### (3) Description Strings

The map description is given in pieces called strings.

(a) Each string may describe all or part of a street and thus may include one or more segments (the portion of a street between two nodes).

(b) A string may occupy part of one card or extend over several cards. A plus sign in column 80 indicates that the string extends to the next card.

(c) The cards are read in free format; i.e., the numbers need not be in specific columns. The order is important, however, and under certain circumstances missing items must be indicated by commas.

(d) The following items make up a string:

street identification number

starting node number

length to next node

refuse quantity from right side

refuse quantity from left side

next node number

/

speed limit

number of ways of travel

number of sides collected on one pass

refuse quantity adjustment factor

} This group may be repeated.

```

(
x coordinate of starting node
,
y coordinate of starting node
)
shape code
(
x coordinate of terminal node
,
y coordinate of terminal node
)

```

The first item in a string is the street identification number. The node number of an intersection or street end point follows. The next four items are the length to the next node (in street-length units); the refuse quantities on the right and left sides of the street, respectively; and the next node number. If refuse quantity is measured by families, the houses should be shown on the maps of the collection area; multiple-family dwellings should be so marked. Terminal decimal points for length and refuse quantity are optional. The node numbers must be positive integers.

(e) The length to next node, refuse quantities on right and left sides of street, and next node number (discussed in the preceding paragraph) are the properties of a segment and may be repeated to add additional segments to the string as long as the street number initiating the string, the shape code (discussed in subsection c), and the four items following the slash [see paragraph (g)] continue to apply to the string as a whole.

(f) If a string must be ended before all of a street with a given name is finished, the description of that street is resumed on the next string.

(g) A slash is punched after the last node number on a string unless all of the remaining items are to be omitted. Following the slash are the speed limit, number of ways of travel, number of sides serviced on one pass, and RQAF. If any of these items are omitted, the default values discussed in subsection b (2) (b), are used. Because these four are positional parameters, missing preceding parameters must be indicated by commas. (Missing trailing

parameters need not be indicated by commas.) Since the positional parameters must apply to all segments of a given string, the string must end if the next segment will require a different value for any of the four parameters.

(h) If a street is one-way, the numeral 1 follows the speed limit (or the comma indicating default speed limit), and the order of nodes on the string must follow the direction of travel.

(i) Very wide streets and those having medians usually require refuse collection on only the right side of the street, so a 1 would be entered as the third parameter after the slash.

(j) If refuse collection is right side only on most of the base, then the default should be changed to a 1; a 2 on a map-description string can then be used to indicate collection from both sides on one pass.

(k) The RQAF is used to adjust (by multiplication) the refuse quantities for all segments on the string. For example, if refuse quantity has been set at one unit per family, then an RQAF of 0.5 could be used as an approximate adjustment for areas housing one person per dwelling.

(l) The string is terminated by coordinates of the first or last nodes, or both. Since one feature of the RCSP is that it produces maps, coordinates are needed for all nodes. In practice, however, coordinates may be punched for fewer than half of the nodes because the permissible shapes of the string allow the program to compute interior node coordinates by interpolation (distance along the string is the independent variable). The coordinates of the first node of the string, measured in the coordinate system appended to the map, follow the last parameter specified after the slash. The two coordinates are separated by a comma, and the pair is enclosed in parentheses. No node may have coordinates (0.,0.) because (0.,0.) or (,) are used to indicate that the coordinates have been specified previously. If all four values after the slash are default values, the coordinates follow immediately after the slash.

(m) If the string does not describe a straight street, a shape code (subsection c) follows the first node coordinates [or follows (,) if the

first node coordinates have been given by a previous string, either by explicit specification or by interpolation]. The coordinates of the terminal node of the string follow the shape code. If the coordinates have already been specified, nothing need follow the shape factor.

#### (4) Example of Construction of Map Description Strings

The straight streets shown in Figure 1 require no shape codes and thus will be used for a first illustration of the construction of description strings. (The more complex problems presented by the streets shown in Figure 2 are addressed in subsection e, after the shape codes have been explained.)

##### (a) First String

The four streets in Figure 1 have already been numbered. The first string can start at node 10, pass through node 20, and end at node 30 because it will describe only street 1 (Sunset Hwy), which has one speed limit for its entire length. The string starts:

1 10 15 0, 0 20 10 0, 0 30 /

The lengths are measured in tenths of an inch, as indicated in the example given for the first card in record 3.

The separation of nodes 10 and 20 is 15 tenths of an inch, and nodes 20 and 30 are 10 tenths of an inch apart.

The refuse quantities are zero because no houses border this street. The right and left quantities could be separated by a blank, but a comma is used here to make it easier to identify the items in the string.

The default speed limit for this map is set at 45 mph. The four default parameters now can be used for the first four items after the slash, so these four items are omitted. The coordinates of nodes 10 and 30 complete the string:

1 10 15 0, 0 20 10 0, 0 30 / (1.5,2) (4,2)

(b) Second String

Street 2 is not drawn to the same scale as the rest of the overall map in Figure 1, so an exception is made to the usual length-measuring procedure. The length from node 20 to node 70 is entered as 75 (tenths of an inch), instead of the actual 10, so that the mileage between these nodes will be 15 miles:

2 70 75 0, 0 20 / (3,3)

When these data are read, a warning will be printed indicating that the scale differs from the standard for this map; but on the computer map, street 2 will appear as in Figure 1.

Note that the coordinates of node 20 were not needed again because they were found by interpolation in the first string.

This string could have been punched in reverse direction as follows:

2 20 75 0, 0 70 / (,) (3,3)

where the (,) indicates that the coordinates of the first node (node 20) have already been given.

(c) Third String

The string for street 3 is done just as for street 1:

3 30 8 0, 0 40 7 0, 0 50 / (,) (4,.5)

except that the (,) indicates that the coordinates of node 30 are already known. The string could also be processed in reverse as follows:

3 50 7 0, 0 40 8 0, 0 30 / (4,.5)

(d) Fourth String

The last string is

4 50 3 0, 0 60 / (,) (4.3,.5)

## (5) Additional Map Description Records

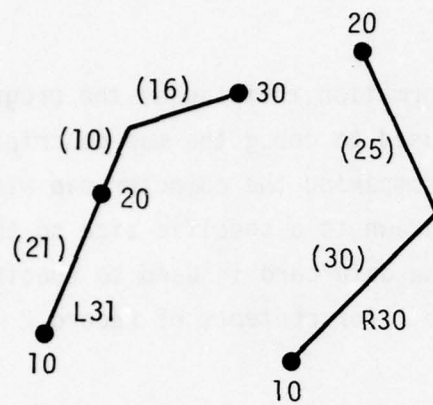
On the first map description string in each record after the third, either the starting or the terminal node must have been used in a previous record. Also, coordinates must be specified for this node in the present map-coordinate system on the first string of the fourth and any subsequent records. This procedure enables the program to transform all coordinates in the present map coordinate system back to the overall system used in the third record. Rotation of a coordinate system is not allowed.

### c. Shape Codes

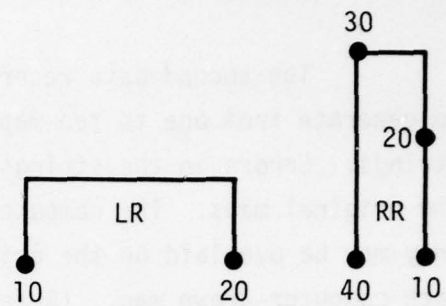
The shape code indicates the type of line actually formed on the map by the street or portion of street represented by a given description string. There are five permissible string shapes: a straight-line segment, two straight-line segments meeting at a point (hereafter referred to as an angle), three sides of a rectangle, a circular arc, and a symmetrical S-curve. For straight strings, no shape code is given in the description string. For the other shapes (Figure 3), the shape code consists of the letter L or R followed by a one- to five-digit number or by one of the letters R, C, or S. Embedded blanks are not allowed.

The leading L or R indicates left or right, respectively, in the following sense: when a line is drawn from the starting node to the terminal node, the area 0+ to 180- degrees on the counterclockwise side is considered the left side, and the area 0+ to 180- degrees on the clockwise side is the right side. If the initial direction of the string from the starting node is to the left of the line, then the L is used; otherwise the R is used.

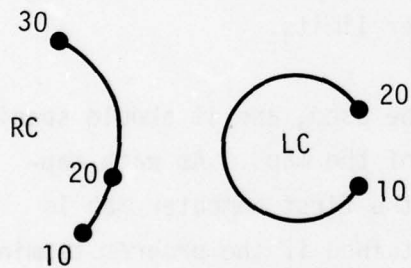
The terminals R, C, and S indicate rectangle, circular arc, or S-curve, respectively. For an angle, the number that follows the lead L or R is the number of length units from the first node of the string to the vertex of the angle. There need not be a node at the vertex, nor need there be interior nodes on any string. If there are interior nodes on an S-curve, either one node must occur at the middle, or the two nodes closest to the middle must be equally spaced about the middle. It may therefore be necessary to add to the S-curve a node that serves no purpose other than to satisfy this constraint.



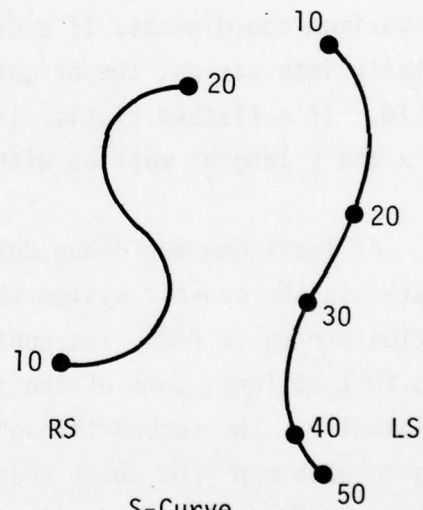
Angle



Rectangle



Circular Arc



S-Curve

- Note: (1) Initial letters L and R (left and right) indicate initial direction of string from starting node in relation to line from starting to ending nodes.
- (2) Terminal letters R, C, and S indicate shape of string.
- (3) Numerals following L or R in angle codes are length units indicating distance from first node to vertex of angle.
- (4) Node 10 is the starting node.

Figure 3. Shape Codes

#### d. Debugging Map Data

The second data record contains information that causes the program to generate from one to ten maps that can be used to debug the map description strings. Errors in the strings are found by comparing the computer map with the original maps. The computer maps can be drawn to a specific size so that they may be overlaid on the original maps. One data card is used to specify each computer-drawn map. (Refer back to Table 1 for contents of record 2 data cards.)

The overall coordinate system from the third data record has sequence number one; the coordinate system used in the fourth record has sequence number two; etc. The minimum and maximum coordinates are in the coordinate system specified by the sequence number. The map lengths are measured between these minimum and maximum coordinates. If a drum plotter is used, the computer map is cut horizontally into strips, the heights of which are indicated in columns 61 through 70. If a flatbed plotter is used, columns 61 through 70 are left blank and the x and y lengths must be within the plotter limits.

At least one map debug data card must be used, and it should specify coordinates in the overall system that span all of the maps. As each map-description string is read, its contribution to the first computer map is drawn so that at least some of the map can be obtained if the program terminates abnormally. The second through tenth cards should specify regions corresponding to each map from which description strings were obtained. The program generates maps for these cards after all of the map description strings have been processed. All of the debugging maps show the streets as single lines (streets will have thickness only on the final route maps). Node numbers are appended near the nodes, and segment numbers are appended near the middle of each segment.

The program allows three options for the definition of node coordinates. The option chosen is indicated by FIRST, LAST, or AVERAGE (or AVG) on the first card of each map description record, starting in column 31. The LAST option causes the program to use the coordinates defined explicitly or by interpolation by the latest node reference. Any variations in node coordinates will then be displayed on the debugging map. The FIRST option causes

the program to use only the coordinates defined the first time a node is referenced. Errors in later references cannot then affect the map. The AVERAGE option causes the program to keep an average of all coordinates defined by each reference to a node. The debugging maps will then show the current average each time a node is referenced, and the final average will be used on the final route maps so that variations in coordinate definitions are smoothed out.

The three options have not been used often enough to show that any one option has definite advantages over another. It is suspected that LAST would be the most useful option during map string debugging, and that AVERAGE or FIRST would be more useful on the final maps. Of course, if all coordinates are specified precisely, all three options will give the same result.

#### e. Example of Map Reduction

The loop housing map in Figure 2 will be used to show in detail the procedure for reducing a map to data cards. Assume that the overall map has been processed (third data record) and that the map in Figure 2 is the next to be processed; the data from it will therefore make up the fourth RCINPT data record. Assume that nodes 100, 110, and 115 were used on the overall map when street 16 was processed.

##### (1) Numbering Streets

First, a coordinate system is appended to the map and the streets are numbered as described in subsection a(1). The numbers and street names are punched on cards and added to the first data record. Recall that four of the five streets having the name East Sandia Drive have been given the suffixes E, S, W, and N to eliminate ambiguous intersection names. The following numbers and names are therefore used for East Sandia Drive in the first data record:

- 36 E Sandia Dr (E)
- 38 E Sandia Dr (S)
- 42 E Sandia Dr
- 43 E Sandia Dr (W)
- 47 E Sandia Dr (N)

## (2) Assigning Node Numbers

Node numbers are assigned next. Note that streets 37, 41, 45, and 49 form shapes that cannot be represented accurately by one of the permissible shape codes; they will therefore be approximated by angles meeting circular arcs. The points at which the angles meet the circular arcs must be given node numbers; these are numbered 200, 260, 410 and 420. (Nodes 450, 460, 470, 480, 490, and 500 are not important on this map; but because they will be used on a later map, they had to be numbered.)

## (3) Indicating Segment Lengths

The length of each street segment is next appended near the middle of the segment. Lengths are also indicated where they are needed as part of an angle shape code.

Once experience with the map reduction procedure has been gained, an examination of the map makes it evident that only 12 nodes must have specified coordinates: nodes 100, 115, 150, 180, 210, 250, 350, 400, 200, 260, 410, and 420. Coordinates for all other nodes will be specified by interpolation if the strings are processed in the proper sequence.

## (4) Reducing Map to Record Cards

(a) The first card in the data record for this map specifies the map scales and the coordinate-use option. The street segment lengths are given in hundredths of a mile, so the length unit (columns 1-10) is left blank. The map scale (columns 11-20) is 625 feet per inch. The coordinate system appended to the map has a scale of 1.0 inch per unit, so 1.0 is placed somewhere in columns 21 through 30. The data are in the debug stage, so the coordinate-use option LAST will go in columns 31 through 34. Thus, each node will be specified on the map each time it is referenced.

(b) The second data card, which gives the default modifiers, can be left blank because the default speed limit of 15 mph applies to most of the map, most of the streets are two-way, collection will be made from both sides

of the street on one pass, and the refuse quantity adjustment factor will be taken as 1.0 because no better estimate is available.

(c) The third card gives the first map description string. Either the starting or the terminal node must have been used on a previous map. Nodes 100, 110, and 115 were used on the overall map for this base, so the first string must describe either street 27, street 42, or street 29. Street 27 will be used first, generating the following string:

```
27 100 19 0,0 190 5 0,0 500 5 0,0 490 5 0,0 480 5 0,0 470 6 0,0 460 5 0,0 450  +
    5 0,0 180/ 25 (4.8,.25) (4.8,4.6)
```

(Since the speed limit is 25 mph, not 15 mph, for street 27, the speed limit must be specified explicitly.)

The remaining peripheral streets are to be processed next. Street 16 has been processed on another map and must not be done again. The strings could continue:

```
28 150 23 0,0 160 11 0,0 170 19 0,0 180/25 (.2,4.65) L37
29 115 20 0,0 120 15 0,0 130 14 0,0 140 5 0,0 150/25 (,) L15 (.2,4.65)
30 130 22 6,6 140 / (,) RR
```

The East Sandia Drive rectangle is processed next. Four strings are needed because each side of the rectangle has a different street number:

```
36 350 6 0,0 430 12 4,2 440 6 1,1 400/ (1.7,3.95) (3.6,3.95)
38 400 6 2,1 390 4 2,1 380 5 0,1 370 8 3,3 360 4 0,0 300  +
    4 0,1 280 6 2,4 250/ (,) (3.55,1.05)
43 210 6 0,0 220 6 0,2 230 6 0,2 240 6 0,0 250/ (1.65,1.05)
47 210 7 2,4 270 4 0,0 290 4 0,0 310 8 4,3 320 4 0,0 330 4  +
    0,0 340 6 4,1 350
```

The rectangles adjacent to the East Sandia Drive rectangle could be processed next. No coordinates need be given because all node coordinates have been obtained by interpolation within the program.

```
44 220 24 7,11 240/ (,) LR
39 300 30 11,12 380/ (,) LR
40 360 24 12,6 370/ ,1 (,) RR
```

35	430	22	10,7	440/	(,)	RR
48	290	30	13,11	330/	(,)	RR
46	320	24	13,6	310/	,1 (,)	RR

The rectangles will be drawn with the corners squared off. If a more accurate map were needed, the corners would be treated as circular arcs, and node numbers would be assigned to the ends of the circular arcs.

Streets 40 and 46 are one-way streets. Note that the speed-limit position has been indicated by a comma, implying the default speed limit, and that the one-way indicator follows the comma.

Some connecting streets could be processed next; a 15-mph speed limit is assumed for these:

42	110	9	0,0	230
31	120	17	0,0	290
32	300	15	0,0	190
33	160	9	0,2	430
34	440	9	0,2	170

The only remaining streets are the one-way loops at the corners of the East Sandia Dr rectangle. Each loop must be processed in the direction of travel:

45	270	14	7,5	200/	,1	(,)	R8	(.95,1.05)
45	200	13	7,5	210/	,1	(,)	RC	
41	250	13	9,5	260/	,1	(,)	RC	(4.25,1.05)
41	260	14	8,5	280/	,1	(,)	R6	
37	390	14	7,6	420/	,1	(,)	R8	(4.25,3.95)
37	420	13	7,4	400/	,1	(,)	RC	
49	350	13	8,4	410/	,1	(,)	RC	(1,3.95)
49	410	14	8,6	340/	,1	(,)	R6	

For a more accurate representation of the shapes of these loops, the part here treated as a circular arc could have been coded as a circular arc and a straight segment.

Note that coordinates were specified explicitly for only 12 of the 42 nodes on the map. The number of coordinates explicitly specified can be kept low if long streets having many interior nodes and streets forming boundaries of large areas of the map are processed first. The following rule decides when coordinates must be specified for a starting or terminal node: coordinates are needed only if the node has not been referred to before.

The map generated by these data appears in Figure 4. Note that the street identification numbers used in the first data record are not displayed on this map. The number near the center of each segment is assigned by RCINPT as the map-description strings are processed. These numbers are used by Programs PHASE2, PHASE3, and PHASE4 to identify the various segments.

## 2. PROGRAM PHASE2

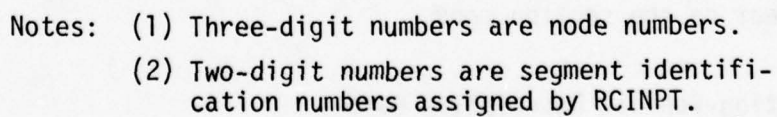
Three data cards are required by PHASE2: a title card, a collection-vehicle description card, and a time-limit card. Up to 10 additional cards may be included; these specify regions to be plotted with section assignments appended to the street segments. If none of these cards are included, one 30-by-30-inch map of the entire region will be drawn. The formats of the data cards are given in Table 2.

### a. Title Card

The title card is used only to put a heading on the printed output and does not appear on the section maps.

### b. Collection-Vehicle Description Card

As many as four different vehicle capacities may be indicated on the vehicle-capacity card. This card causes PHASE2 to operate in one of two modes: (1) If the number of vehicles specified is more than adequate to service the entire collection region, all of the vehicles will be used; (2) If the number of vehicles specified is inadequate, the vehicles will be reused in the order given until all refuse can be collected. In addition, if the numbers of



28

TABLE 2. PHASE2 DATA CARDS

Card	Columns	Format	Contents
1	1-80	8A10	Title
2	1-10	I10	Number of vehicles of the first kind
	11-20	F10.0	Capacity of vehicles of the first kind
	21-30	I10	Number of vehicles of the second kind
	31-40	F10.0	Capacity of vehicles of the second kind
	41-50	I10	Number of vehicles of the third kind
	51-60	F10.0	Capacity of vehicles of the third kind
	61-70	I10	Number of vehicles of the fourth kind
	71-80	F10.0	Capacity of vehicles of the fourth kind
3	1-10	F10.0	Stop time per household, in minutes
	11-20	F10.0	Stop time per unit refuse, in minutes
	21-30	F10.0	Unloading time, in minutes
	31-40	F10.0	Maximum trip time, in hours
	41-50	I10	First section starting segment number
The following card is optional and may be repeated up to 10 times.			
4	1-10	F10.0	Minimum x coordinate of map
	11-20	F10.0	Maximum x coordinate of map
	21-30	F10.0	Length of map in x (horizontal) direction, in inches
	31-40	F10.0	Minimum y coordinate of map
	41-50	F10.0	Maximum y coordinate of map
	51-60	F10.0	Length of map in y (vertical) direction, in inches
	61-70	F10.0	Height of map strips, in inches

available vehicles of each capacity are specified, sections are assigned in such a way that vehicles are used in the order they are specified.

If one pass through the vehicle cards does not provide enough vehicles to collect all of the refuse, use of the vehicles is repeated until the necessary capacity is available. For example, if only one 16-cubic-yard-capacity vehicle is available, a 0 or a 1 in column 10 will produce the minimum number of trips using that vehicle. On the other hand, if four vehicles are available and they are all to be used, even though fewer than four are actually needed, then the number 4 would be specified in column 10. Suppose that two 16-cubic-yard vehicles and one 10-cubic-yard vehicle are available, but each must make more than one trip. If the program user specifies 2 for the number of 16-cubic-yard vehicles and 1 for the number of 10-cubic-yard vehicles, PHASE2 will determine the minimum number of trips by repeatedly using first the two 16-cubic-yard vehicles and then the 10-cubic-yard vehicle until enough capacity is available to collect all the refuse.

c. Time-Limit Card

The time-limit card contains five items. The first entry is the average time in minutes that the vehicle is stopped at each household. The second entry specifies additional stop time for each unit of refuse collected. Usually only the first of these numbers is used because precise stop-time information is seldom available. The third entry is the time in minutes required to unload the vehicle at the landfill. The fourth item is the maximum time, in hours, allowed for any trip. This fourth number can cause vehicles to be scheduled so that they must carry less than a full load, which may necessitate some additional trips. The maximum trip time is approximate, since PHASE2 does not know which streets will be traversed twice or dropped from the section. If the maximum trip time is left blank, 24 hours will be used. The last entry is the number of the segment with which sectioning will begin. If this number is omitted, sectioning begins with the first segment from the first map description string.

The choice of the segment to be used first in the sectioning process can affect the quality of the sectioning performed by PHASE2, since PHASE2

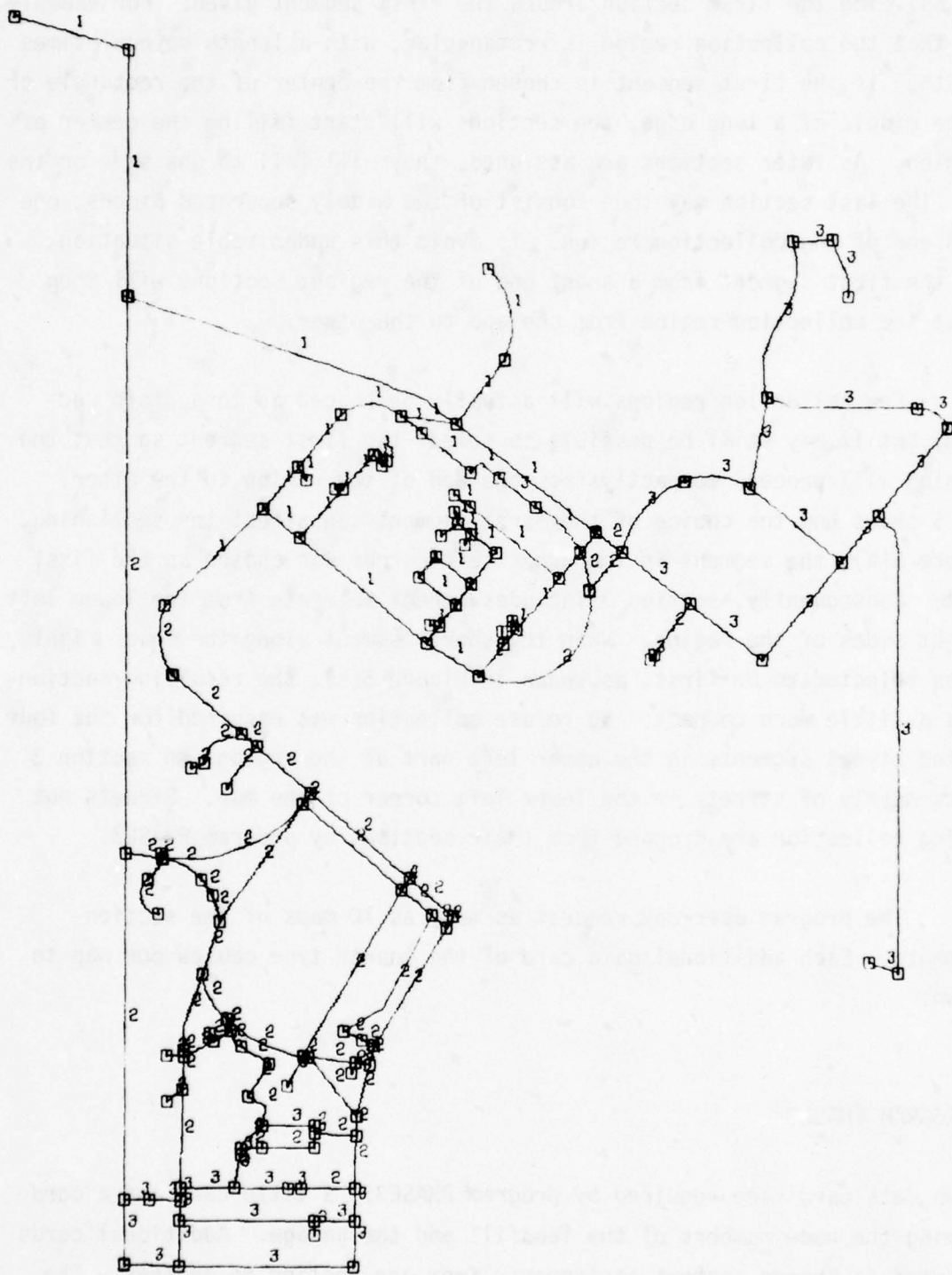
starts building the first section around the first segment given. For example, assume that the collection region is rectangular, with a length several times its width. If the first segment is chosen from the center of the rectangle or from the middle of a long edge, the sections will start filling the center of the region. As later sections are assigned, they will fall to one side or the other. The last section may then consist of two widely separated pieces, one at each end of the collection region. To avoid this undesirable situation, choose the first segment from a short end of the region; sections will then fill out the collection region from one end to the other.

Few collection regions will actually be shaped as long, thin rectangles, but it may still be possible to select the first segment so that the sectioning will proceed compactly from one end of the region to the other. Figure 5 shows how the choice of the first segment can affect the sectioning. In Figure 5(a), the segment in the upper left corner was chosen as the first segment. Consequently, section 3 includes street segments from the lower left and right sides of the region. When the short segment along the lower right edge was selected to be first, as shown in Figure 5(b), the resulting sectioning was a little more compact. No refuse collection was required for the four connected street segments in the upper left part of the region, so section 3 consists mostly of streets in the lower left corner of the map. Streets not requiring collection are dropped from their sections by program PHASE3.

The program user may request as many as 10 maps of the section assignments. Each additional data card of the fourth type causes one map to be drawn.

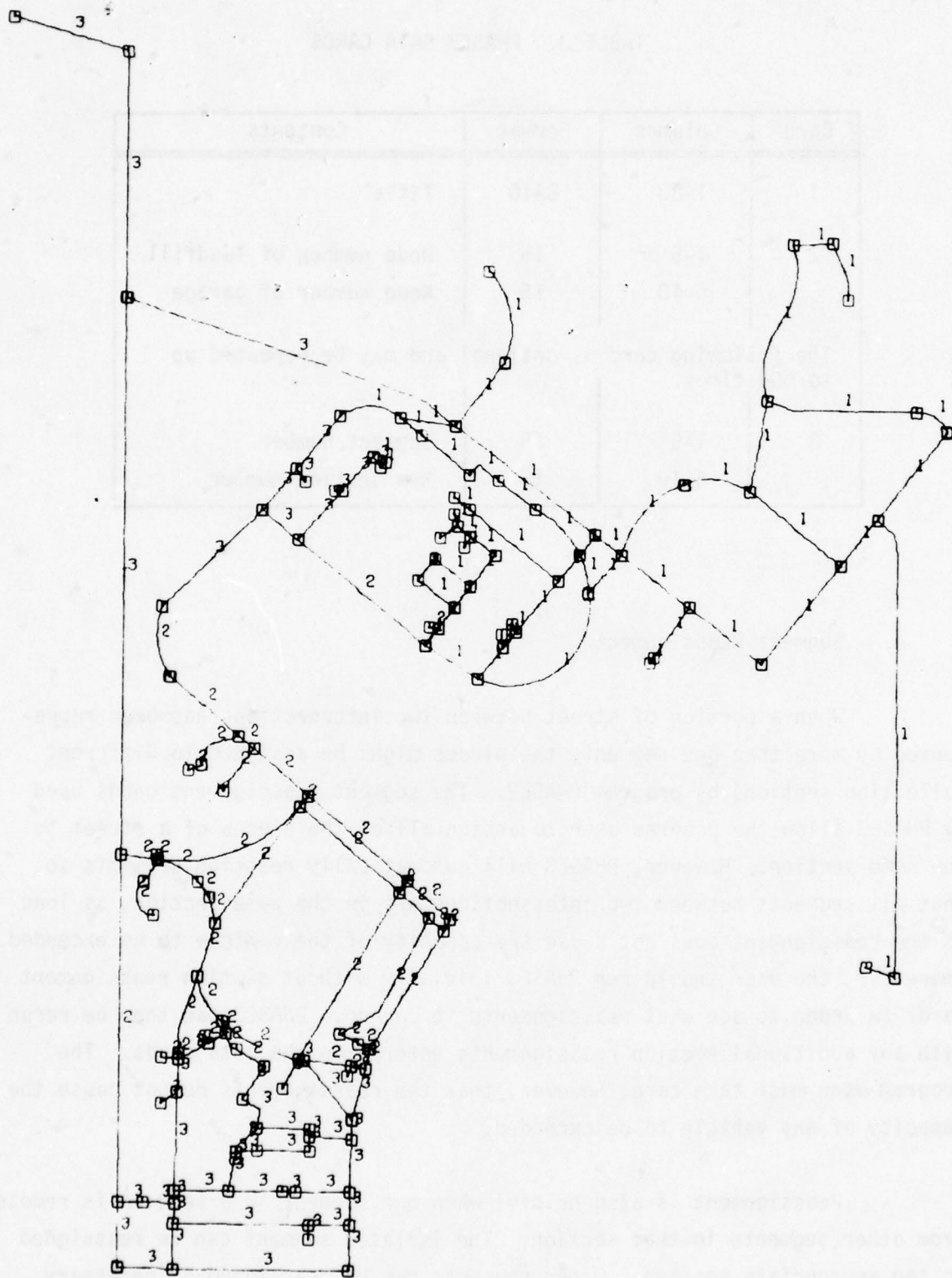
### 3. PROGRAM PHASE3

Two data cards are required by program PHASE3: a title card and a card specifying the node numbers of the landfill and the garage. Additional cards may be used to change segment assignments from one section to another. The contents and formats of the data cards are given in Table 3.



(a) Initial Assignments, Sections 1, 2, 3

Figure 5. Section Assignments



(b) Improved Assignments, Sections 1, 2, 3

Figure 5. Section Assignments (Concluded)

TABLE 3. PHASE3 DATA CARDS

Card	Columns	Format	Contents
1	1-80	8A10	Title
2	1-5	I5	Node number of landfill
	6-10	I5	Node number of garage
The following card is optional and may be repeated up to 500 times.			
3	1-5	I5	Segment number
	6-10	I5	New section number

a. Segment Reassignment

When a portion of street between two intersections has been represented by more than one segment, the pieces might be assigned to different collection sections by program PHASE2. The segment reassignment cards used by PHASE3 allow the program user to assign all of the pieces of a street to the same section. However, PHASE3 will automatically reassign segments so that all segments between two intersections are in the same section, as long as the reassignment does not cause the capacity of the vehicle to be exceeded. Therefore, the user should run PHASE3 initially without section reassignment cards in order to see what reassignments it can do. PHASE3 can then be rerun with any additional section reassignments entered on the data cards. The program user must take care, however, that the reassignments do not cause the capacity of any vehicle to be exceeded.

Reassignment is also helpful when one segment in a section is remote from other segments in that section. The isolated segment can be reassigned to the appropriate section. Other segments can be reassigned if necessary to prevent any vehicle from being overfilled.

b. One-Way Street Problems

Two problems involving one-way streets require human intervention in the program. In both cases, the following error message is printed:

NO PATH EXISTS FOR THE TRIP STARTING AT THE  $\alpha$

where  $\alpha$  is either GARAGE or LANDFILL. In one case, program routing will force the vehicle to travel against traffic on a one-way street, and PHASE3 prints the following warning:

TRAVEL PATH CANNOT BE FOUND. RECHECK NETWORK FOR THIS TRIP.

(This same message can indicate other problems, so the segments in the current trip [section] should be examined for obvious errors.) The one-way street problem can be bypassed in two ways. The street can be changed to a two-way street in the RCINPT data, and RCINPT and PHASE2 can be rerun. If the routing still shows that the street must be traversed in the wrong direction when the output from PHASE3 has been plotted by PHASE4, the path description on file TAPE9 should be punched and modified by hand, and the modified cards should be used as input to PHASE4. The alternative is to use the section reassignment cards, moving streets into the section to provide a two-way path between pieces of the section.

The other one-way problem causes PHASE3 to print this warning:

NCH=20 QUITTING

Part of the distance minimization performed by PHASE3 requires paths to be found between pairs of nodes where an odd number of street segments meet (odd nodes). The paths are chosen to minimize the total distance between pairs of odd nodes. If one of these paths includes a one-way street, the pairing algorithm may fail to converge within the normal 20 iterations. One solution, again, is to change the one-way street to a two-way street. The alternative is to use the section reassignment cards to add or remove segments from the odd nodes, making them even. The program does not indicate which odd nodes are involved. Usually they are closer to one another than to other odd nodes and are connected, on the shortest path between them, by a one-way street.

If either of the warnings is printed without the error message, PHASE3 has bypassed the problem and no human intervention is necessary.

#### 4. PROGRAM PHASE4

Four types of data are required for program PHASE4 and three more types are optional. The required data are a title card, a refuse-unit card, time-restriction cards, and vehicle-information cards. The optional data are map-bounds, street-name, and path information cards. The structure of the data deck is given in Table 4.

##### a. Title Card

The first data card contains information that is appended to the maps and the schedule printed by program PHASE4. This information normally would include the name of the base for which refuse collection is being scheduled.

##### b. Refuse-Unit Card

The second card contains the name of the unit of refuse (e.g., cubic feet) in columns 1 through 20.

A provision exists for pairing single trips by placing the digit 1 in column 25 of this card. Program PHASE3 produces two alternatives for each section, one trip starting at the garage, and one trip starting at the landfill. Program PHASE4 pairs trips to produce the minimum total travel distance. If the original routes are to be plotted, two choices for each section are not available. The single trips can be paired by using a 1 in column 25 so that the first trip starts at the garage and the next trip starts at the landfill. If column 25 is left blank and only one trip per section is given in the path data, the trips will be treated as individual trips, all starting at the garage. Each vehicle will then make one trip per day.

##### c. Street Name and Number Cards (Optional)

The street names and corresponding numbers are placed on a disk or tape by program RCINPT. If the user wishes to change this information, or if the information has not been saved by program RCINPT, the street names and

TABLE 4. PHASE4 DATA CARDS

Record	Card	Columns	Format	Contents	
1	1	1-80	8A10	Title	
	2	1-20	2A10	Refuse units	
		21-25	I5	Trip pairing control	
The following card is optional and may be repeated up to 300 times.					
End of Record	3	1-5	I5	Street number (right justified)	
		11-60	5A10	Street name (left justified)	
				7-8-9 multipunched in column 1.	
If card 3 is omitted, omit End of Record and append the next 3 cards to record 1.					
2	1	1-10	F10.0	Stop time per household, in minutes	
		11-20	F10.0	Stop time per unit refuse, in minutes	
		21-30	F10.0	Unloading time, in minutes	
		31-40	F10.0	Maximum trip time, in hours	
		41-50	F10.0	Maximum working time per day, in hours	
		51-60	F10.0	Starting time, in hours	
		61-70	F10.0	Average vehicle speed, in mph, between two collection points on a street	
	2	1-10	F10.0	Duration of lunch, in minutes	
		11-20	F10.0	Starting time of lunch, in hours	
		21-30	F10.0	Duration of first break, in minutes	
		31-40	F10.0	Starting time of first break, in hours	
		41-50	F10.0	Duration of second break, in minutes	
		51-60	F10.0	Starting time of second break, in hours	
		The following card may be repeated up to 10 times.			
		3	1-10	F10.2	Vehicle capacity
11-60	5A10		Vehicle identification		
End of Record			7-8-9 multipunched in column 1.		

TABLE 4. PHASE4 DATA CARDS (Concluded)

Record	Card	Columns	Format	Contents		
The following card is optional and may be repeated up to 100 times.						
3	1	1-5	I5	Section number		
		6-10	I5	AM/PM trip indicator		
		11-20	F10.0	Minimum x coordinate		
		21-30	F10.0	Maximum x coordinate		
		31-40	F10.0	Length of x direction, in inches		
		41-50	F10.0	Minimum y coordinate		
		51-60	F10.0	Maximum y coordinate		
		61-70	F10.0	Length of y direction, in inches		
End of Record			7-8-9 multipunched in column 1.			
The following record is used only if path data are not on file TAPE9.						
4	1	1-5	I5	Section number		
		6-10	F10.3	Total distance for this piece of the trip, in miles		
		11-15	I5	AM/PM trip indicator		
		16-25	F10.3	Vehicle capacity		
		26-35	F10.3	Total refuse quantity for this trip		
	2	1-5	I5	Node number		
		6-9	I4	Segment number		
		10	A1	Travel/Collection indicator		
		The above three items may be repeated to the end of the card. This card is repeated until the entire path to the collection region has been described.				
		The two cards are used twice more for each trip, once to describe the path in the collection region and again to describe the path from the collection region to the landfill.				
End of Record			7-8-9 multipunched in column 1.			

numbers may be inserted in the data at this point. The street information is terminated by an end-of-record card. If street information is present, the time-limit cards become the first two cards of record two; otherwise, they become the third and fourth data cards in record one.

d. Time-Limit Cards

The first two items on the first time-limit card are the stop time per household and the stop time per unit of refuse, both in minutes. If the stop time per household were 30 seconds, it would be entered as 0.5 minutes.

The stop time per household and the stop time per unit of refuse are additive. Usually only one of the two is specified because stop-time information is seldom accurate enough to provide both numbers.

The fourth entry on the time-limit card, the maximum trip time, excludes time for lunch and break time. The fifth entry, the maximum working time per day, includes break and lunch time. These numbers will be enforced where possible, but if both choices of trip for a section exceed the maximum time, then the maximum trip time will be increased. If the increase in trip time proves unsatisfactory, then the sectioning must be done again by program PHASE2 with more severe time restrictions on each trip.

The fourth entry, the starting time, is represented in decimal hours; thus a starting time of 7:45 a.m. would be entered on the data card as 7.75. If no starting time is specified, a starting time of 8:00 a.m. will be used.

If the seventh entry, the average speed between collection points on one segment, is omitted, then an average speed of 5 miles per hour will be used.

The second time-limit card contains the durations and approximate starting times for lunch and two breaks. Break and lunch times will start as soon after the given starting time as a street segment is completed.

e. Vehicle-Information Cards

From one to ten vehicle-information cards must be included in PHASE4. The vehicle capacity must match that used by program PHASE2. The vehicle-information cards are terminated by an end-of-record card.

f. Map-Bounds Cards (Optional)

The next record consists of map-bounds cards, which indicate the region to be drawn for each section. If the map-bounds cards are omitted, then program PHASE4 will select a region that includes collection but not necessarily travel to and from the garage or landfill. It may be necessary to break the map of a section into several maps in order to obtain a suitable scale. The map-bounds data record must be terminated by an end-of-record card even if no map-bounds data are used.

g. Path-Information Cards (Optional)

The information describing the path for each trip usually comes from file TAPE9 produced by program PHASE3. If data cards describing the paths are to be used, they follow the map-bounds data record. Each trip is broken into three pieces. The first piece describes travel from the garage or landfill to the collection region. The second piece describes travel and collection in the collection region up to the end of the last collection. The third piece describes travel from the last collection point to the landfill. There is a header card for each of these three pieces. Each header card gives the section number, the total distance in miles for this piece of the trip, either digit 1 or digit 2 to indicate whether the trip started at the garage or at the landfill, the vehicle capacity, and the total amount of refuse to be collected during this trip.

Travel on the piece is described by repeating three items: a node number, a segment number, and the letter T or C to indicate travel or collection on that segment. The format used for each card is 8(I5, I4, A1); eight segments can be placed on one card. The number of the node terminating the trip follows the three items for the last segment.

Where two choices are given for each trip, one starting at the landfill and one starting at the garage, each choice would be represented by the three pieces. The trip starting at the garage must occur first. The path from the landfill back to the garage occurs at the beginning of the path data. Its header card need only indicate the number of segments in the path.

## APPENDIX A

### PROGRAM CHARACTERISTICS

The largest map description that can be processed by the CERF RCSP uses 500 street segments, 300 nodes, and 300 street names. Input to program RCINPT can include 700 segments and 500 nodes, but the map description must then be reduced to 500 segments and 300 nodes by removing streets or by using simpler approximations of the street shapes. The largest number of trips that can be scheduled is 50. As many as 50 vehicles, but not more than four different vehicle capacities, may be used. Each of the following trips may not exceed 100 street segments: travel from garage or landfill to collection area; travel within collection area, travel from collection area to landfill, and travel from landfill to garage. This last restriction is not directly enforceable by the program user, but he should have no difficulty with a problem involving 500 or fewer segments and five or more trips.

The memory requirement for program RCINPT is approximately 73,000<sub>8</sub> words. The times for the largest possible problem, a 500-segment map, should not exceed 60 seconds CP time, 60 seconds I/O time, and 100 seconds PP time. The files used by RCINPT are described in Table A-1. Files 1 and 2 are used as input by the remaining programs (PHASE2, PHASE3, and PHASE4). File 3 is used as input by program PHASE4. These three files may be permanent disk files.

The memory requirement for program PHASE2 is approximately 116,000<sub>8</sub> words. The times for the largest possible problem should not exceed 120 seconds CP time, 120 seconds I/O time, and 200 seconds PP time. The files used by PHASE2 are described in Table A-2. Files 1 and 4 are used as input by PHASE3. File 9 is the segment data written by RCINPT as file 1. File 11 is the node data written by RCINPT as file 2.

The memory requirement for program PHASE3 is approximately 123,000<sub>8</sub> words. The times for the longest possible problem should not exceed 18 minutes CP time, 3 minutes I/O time, and 6 minutes PP time. For more typical runs of 200 to 400 segments and 10 to 20 sections, the times should not exceed 6 minutes CP time, 1 minute I/O time, and 1 minute PP time. The files used by PHASE3 are described in Table A-3. File 9 is used as input by program PHASE4.

TABLE A-1. RCINPT FILE DESCRIPTION

File Number	Contents	I/O Type	Maximum Length, words
1	Segment Data	Binary Write	9,000
2	Node Data	Binary Write	2,600
3	Street Numbers and Names	Buffer Out	1,000
5	Data Cards	Formatted Read	7,000
8	Calcomp Plot Tape	Depends on Local System	1,500,000

TABLE A-2. PHASE2 FILE DESCRIPTION

File Number	Contents	I/O Type	Maximum Length, words
1	Vehicle Data	Binary Write	152
2	Temporary Storage	Formatted Read/Write	500
3	Temporary Storage	Formatted Read/Write	500
4	Section Assignments	Formatted Write	500
5	Data Cards	Formatted Read	104
7	Temporary Storage	Formatted Read/Write	6,500
8	Calcomp Plot Tape	Depends on Local System	1,500,000
9	Segment Data	Binary Read	9,000
10	Temporary Storage	Binary Read/Write	20,000
11	Node Data	Binary Read	2,600

TABLE A-3. PHASE3 FILE DESCRIPTION

File Number	Contents	I/O Type	Maximum Length, words
1	Segment Data	Binary Read	9,000
2	Node Data	Binary Read	2,600
3	Vehicle Data	Binary Read	1,000
4	Section Assignments	Formatted Read	500
5	Card Input	Formatted Read	4,016
7	Temporary Storage	Buffer In/Out	3,601
9	Route Description	Formatted Write	33,800

The memory requirement for program PHASE4 is approximately 111,000<sub>8</sub> words. The total running time is roughly dependent upon the number of maps produced. The following estimates should be adequate for compilation and execution:

CP time = 12 seconds + 2.5 seconds x (number of maps)

I/O time = 12 seconds + 2.5 seconds x (number of maps)

PP time = 60 seconds + 3 seconds x (number of maps)

The files used by PHASE4 are described in Table A-4.

TABLE A-4. PHASE4 FILE DESCRIPTION

File Number	Contents	I/O Type	Maximum Length, words
1	Segment Data	Binary Read	9,000
2	Node Data	Binary Read	2,600
3	Street Numbers and Names	Buffer In	1,000
5	Card Input	Formatted Read	36,000
8	Calcomp Plot Tape	Depends on Local System	30,000,000
9	Route Description	Formatted Read	33,800

## APPENDIX B

### DECK SETUP

Preparation of the RCSP begins either with decks of the four programs (RCINPT, PHASE2, PHASE3, and PHASE4) or with a tape with card images of the four programs. Each subroutine and main program has a unique \*DECK card as shown in Figures B-1 through B-4. An UPDATE program library is generated first, using the deck shown in Figure B-5. Executable binary versions of the program are then prepared and cataloged using the deck shown in Figure B-6.

The most general data deck structures for the four programs are shown in Figures B-7 through B-10. The deck setups for running the four programs are shown in Figures B-11 through B-14.

Permanent file names are arbitrary. The names chosen (NODES, SEGMENTS, STREETS, TRUCKS, ARCS, and ROUTES) are indicative of the nature of the data saved. If more than one base is being processed at one time, the permanent file names should start with one or more letters from the base name so that unique permanent file names will be created.

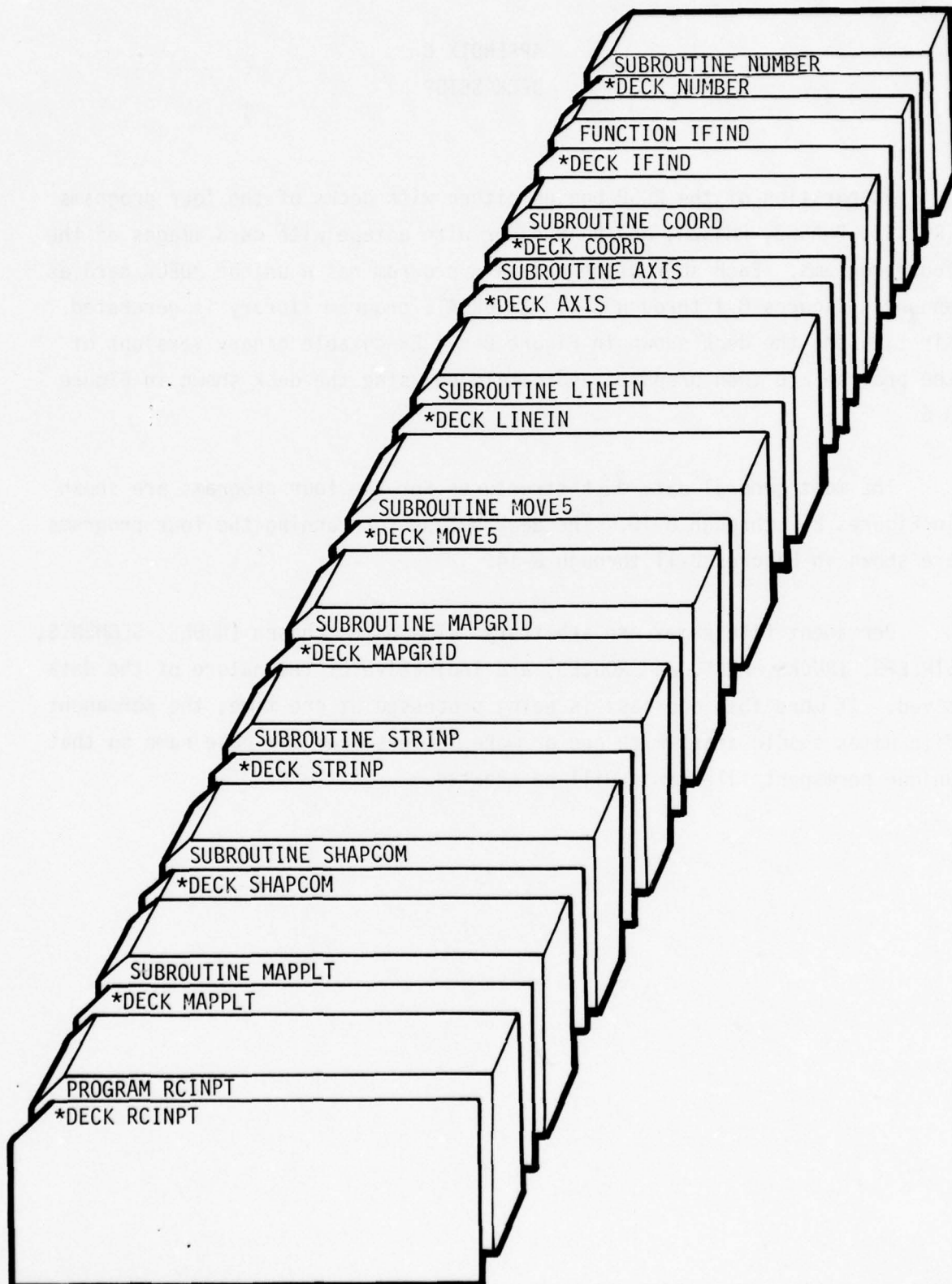


Figure B-1. Deck Setup for Program RCINPT

Note: Decks COORD, IFIND, and  
NUMBER from Program  
RCINPT are also required.

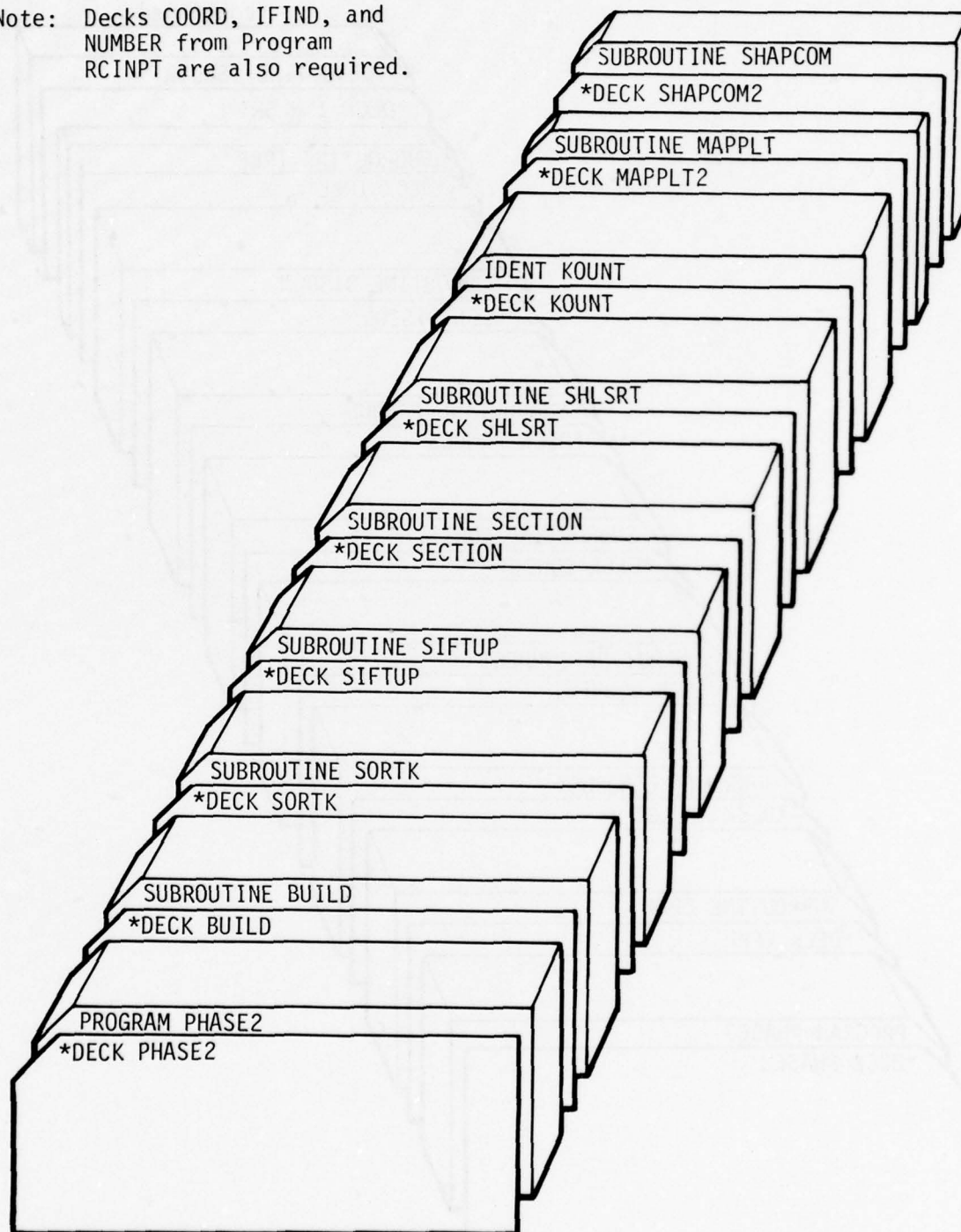
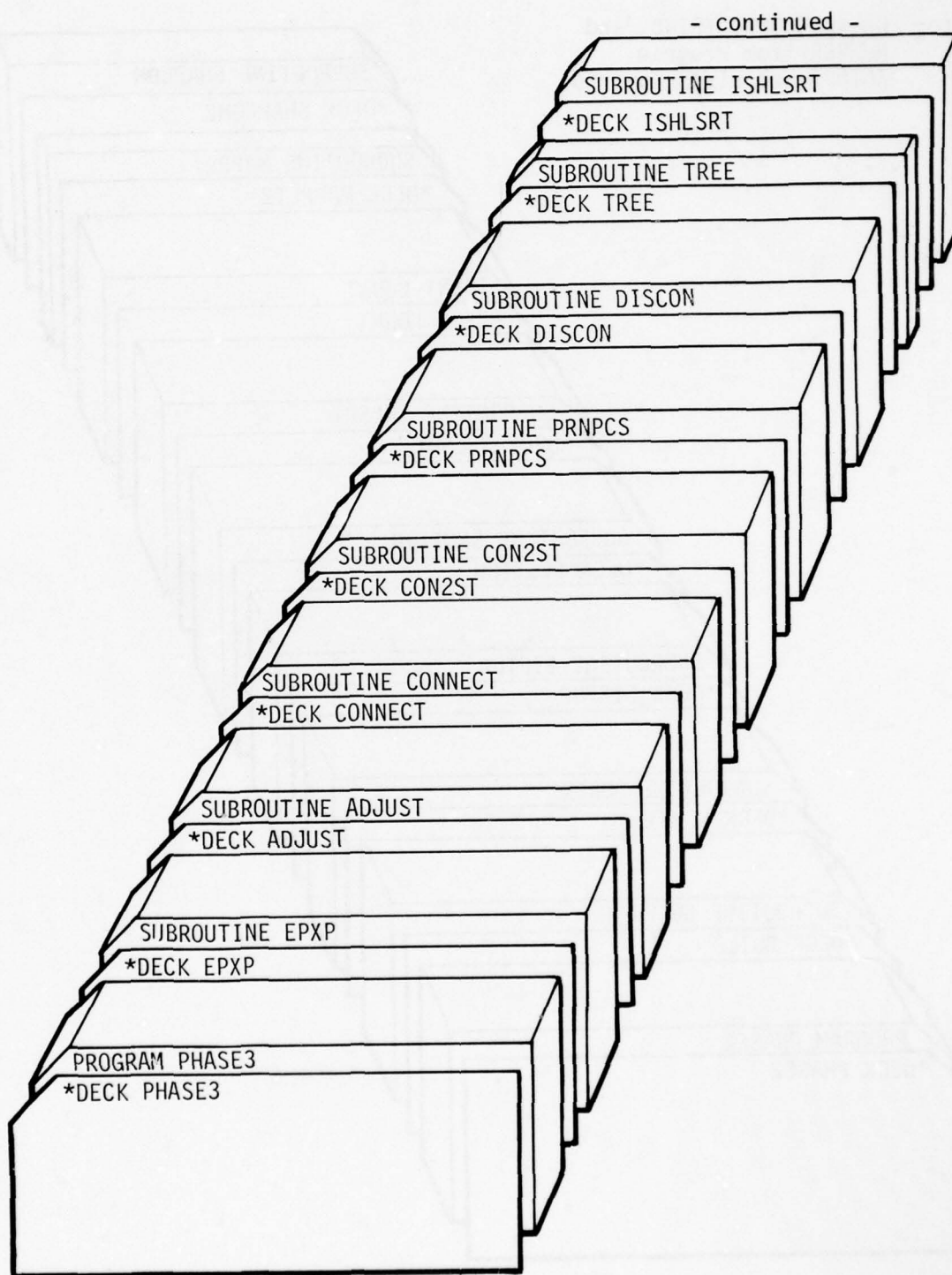


Figure B-2. Deck Setup for Program PHASE2



Note: Deck IFIND from Program RCINPT is also required.

Figure B-3. Deck Setup for Program PHASE3

- continued -

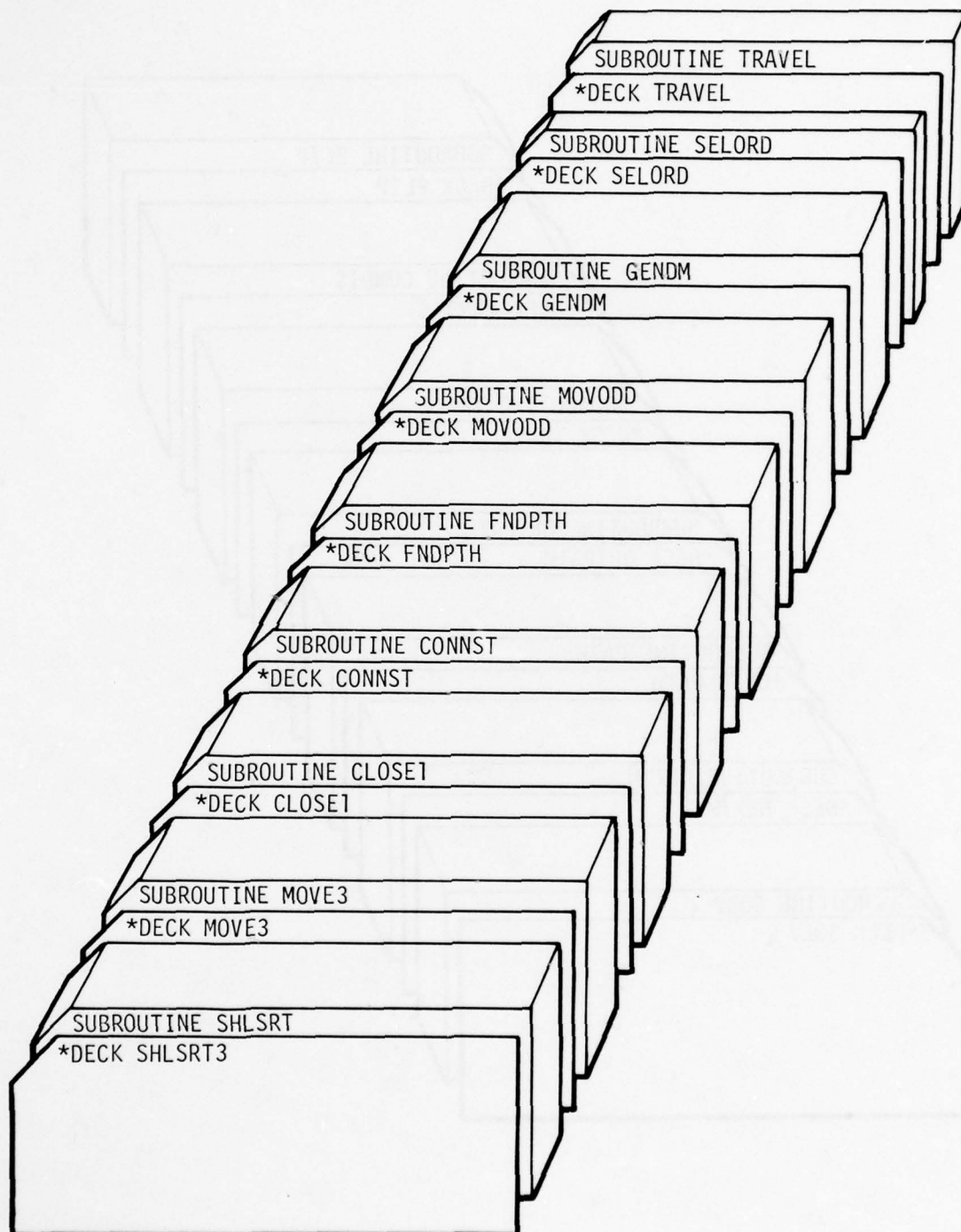


Figure B-3. Deck Setup for Program PHASE3 (Continued)

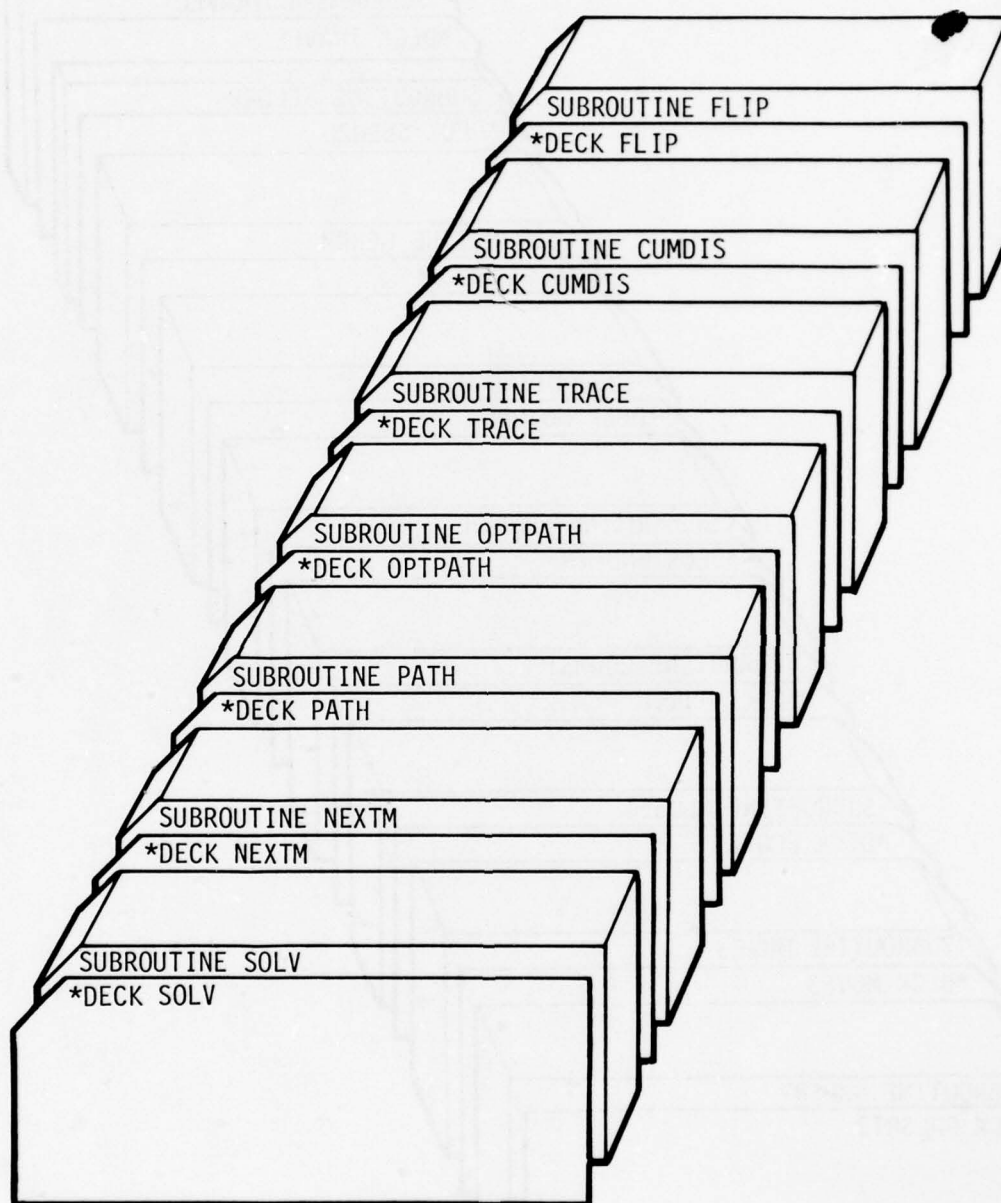
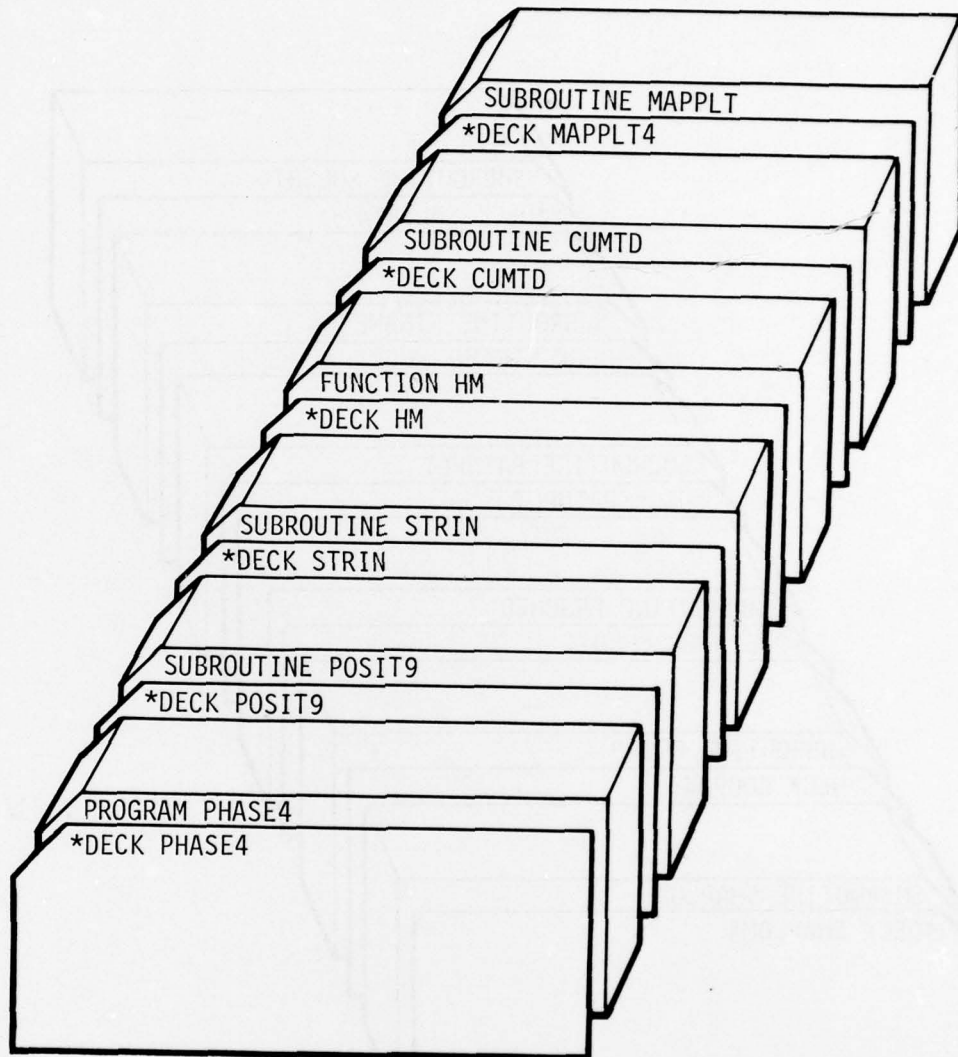


Figure B-3. Deck Setup for Program PHASE3 (Concluded)

- continued -



Note: Decks IFIND and NUMBER from  
Program RCINPT are also  
required.

Figure B-4. Deck Setup for Program PHASE4

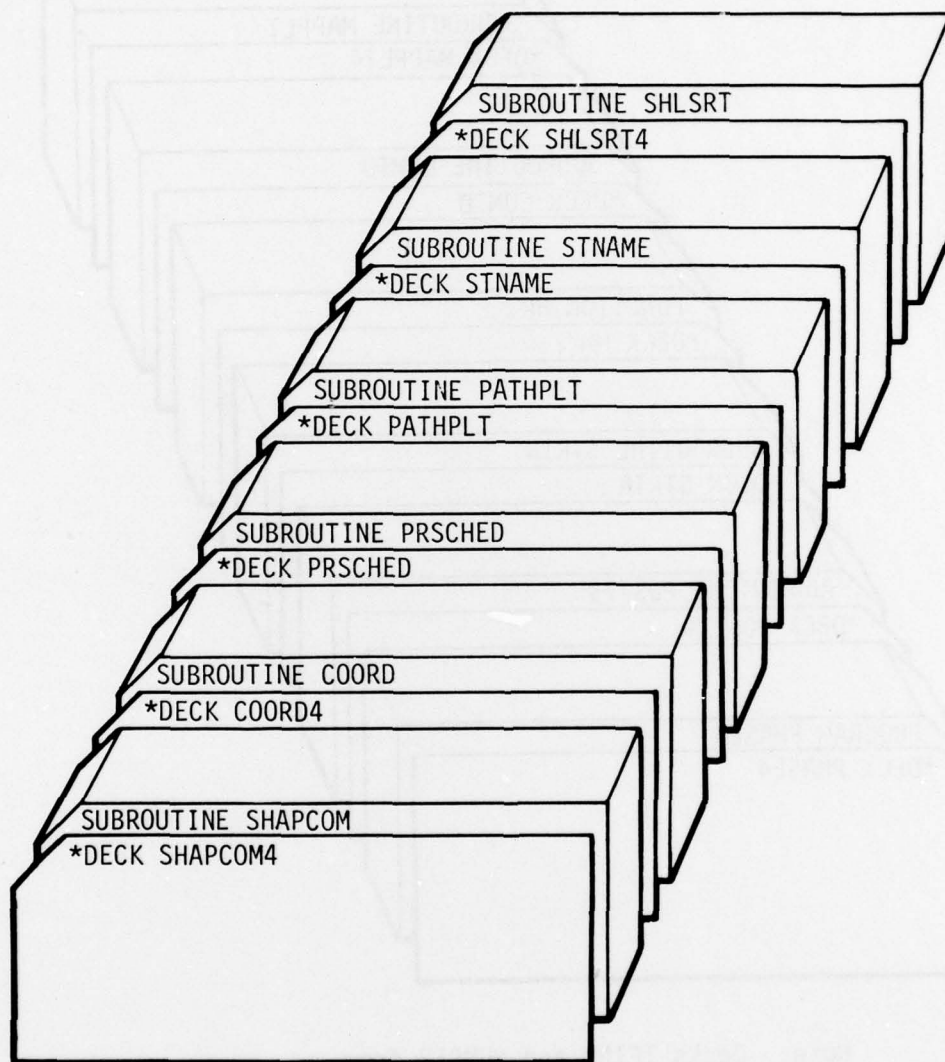


Figure B-4. Deck Setup for Program PHASE4 (Concluded)

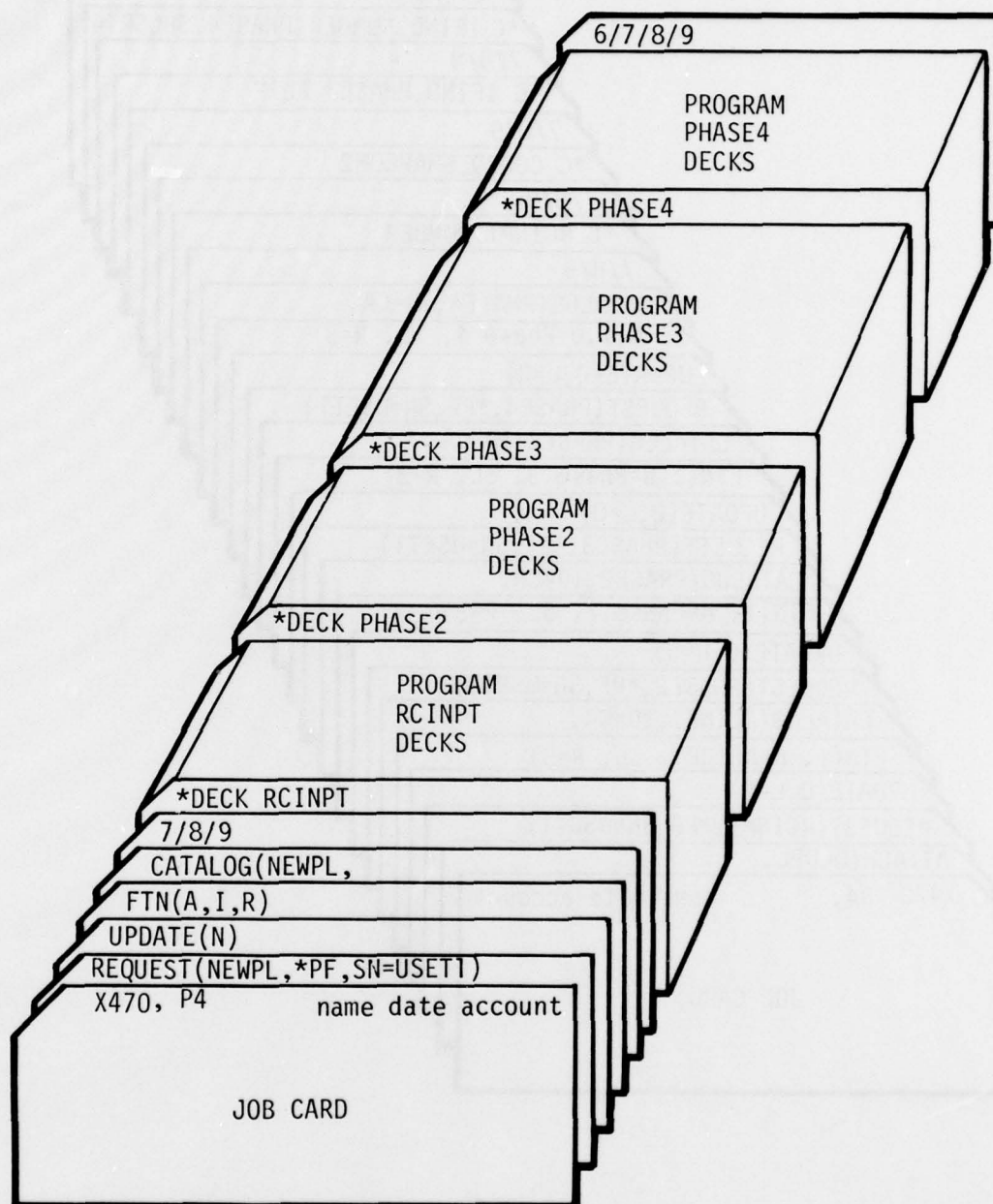


Figure B-5. Deck Setup for UPDATE Library Generation

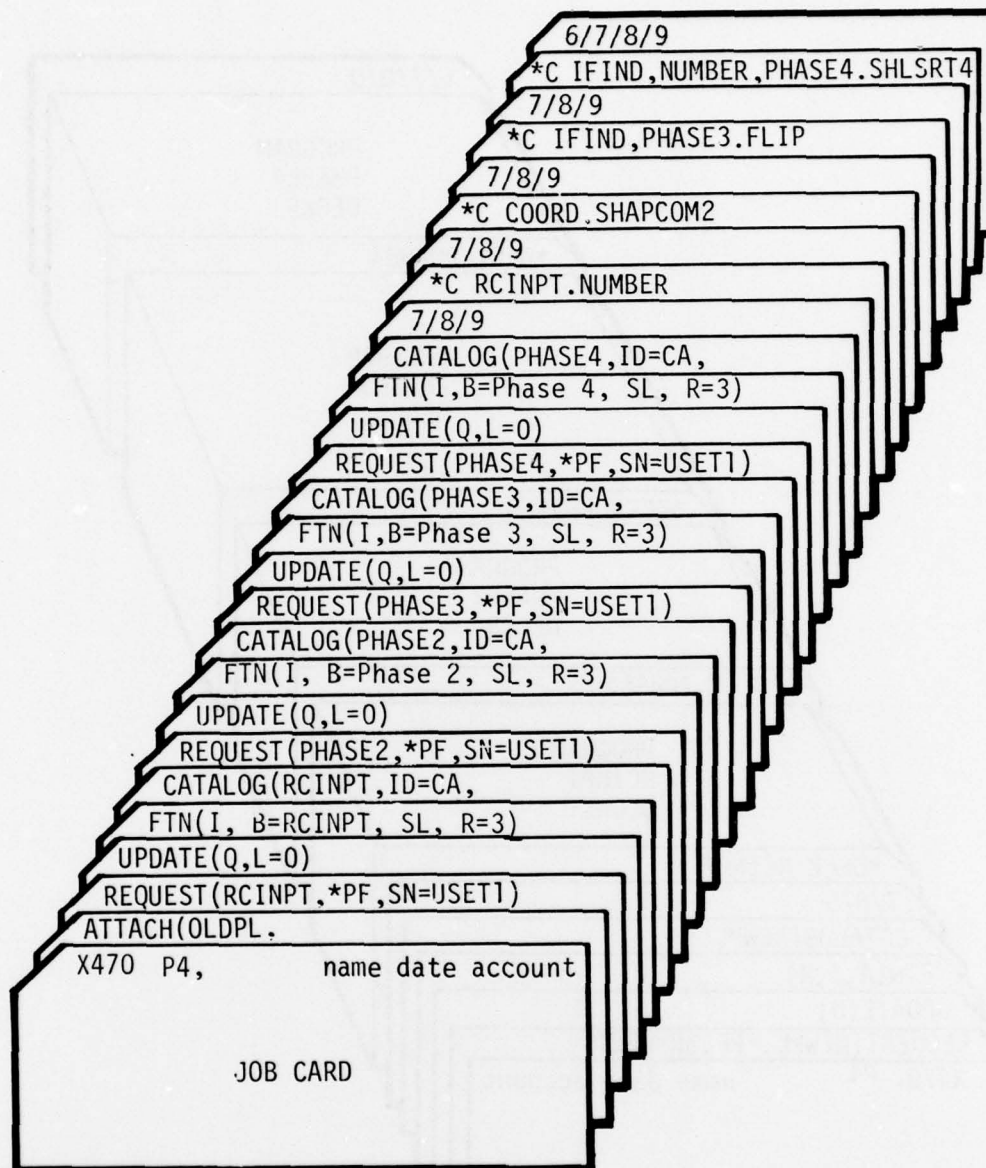


Figure B-6. Deck Setup for Generating Executable Binary Programs

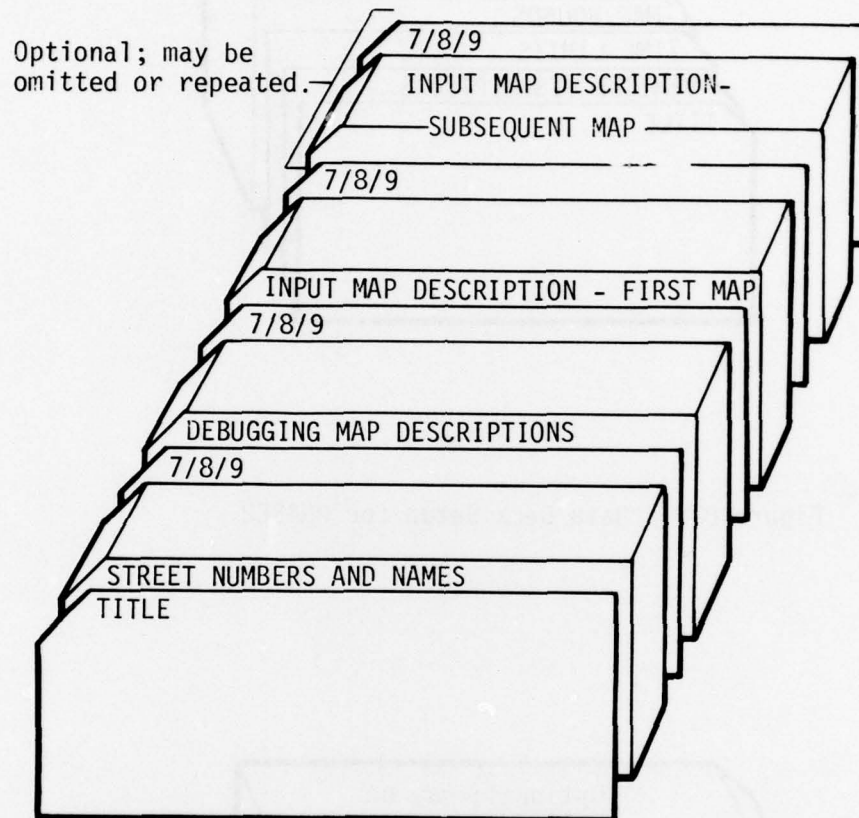


Figure B-7. Data Deck Setup for RCINPT

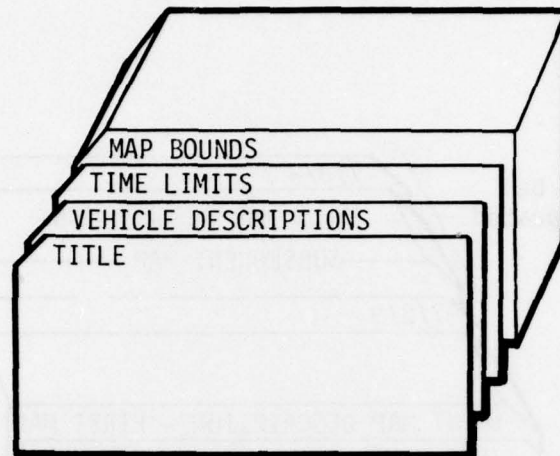


Figure B-8. Data Deck Setup for PHASE2

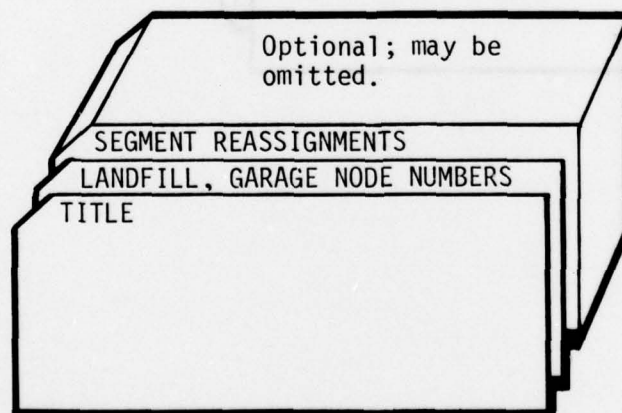


Figure B-9. Data Deck Setup for PHASE3

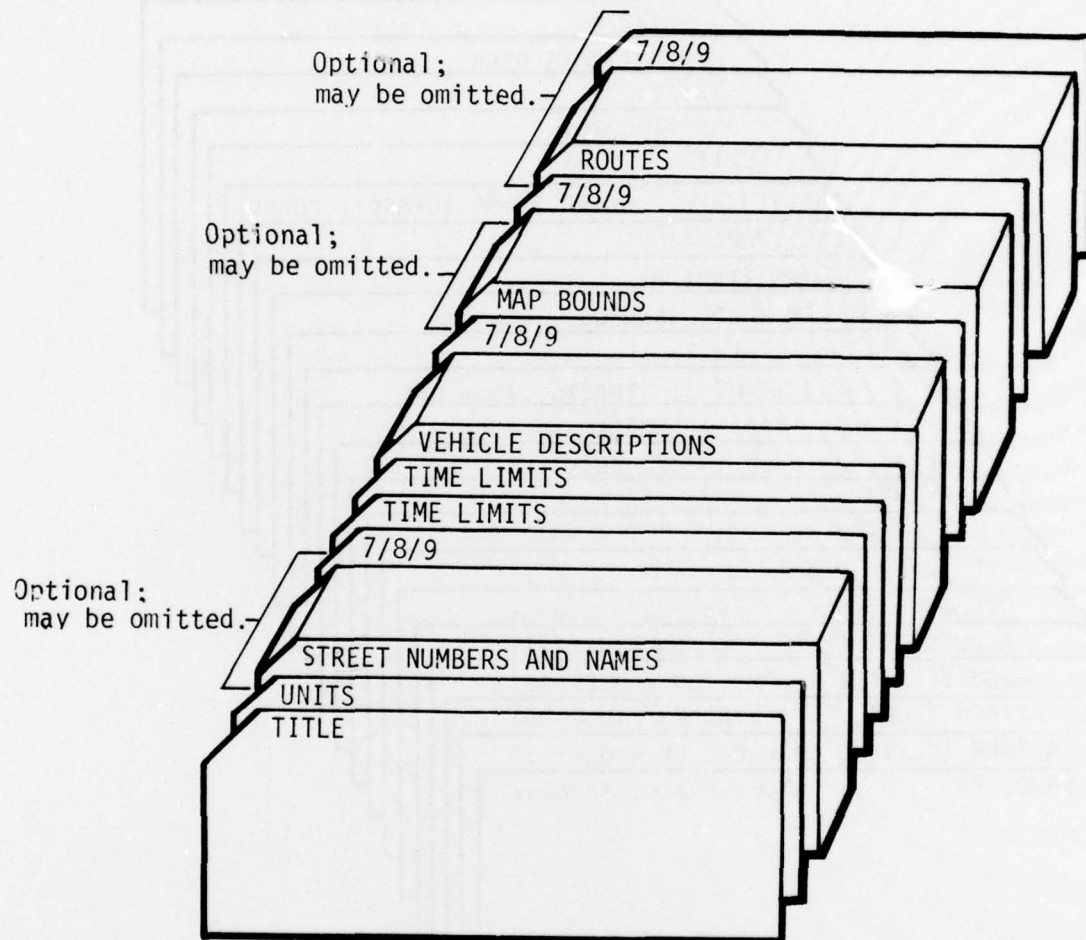


Figure B-10. Data Deck Setup for PHASE4

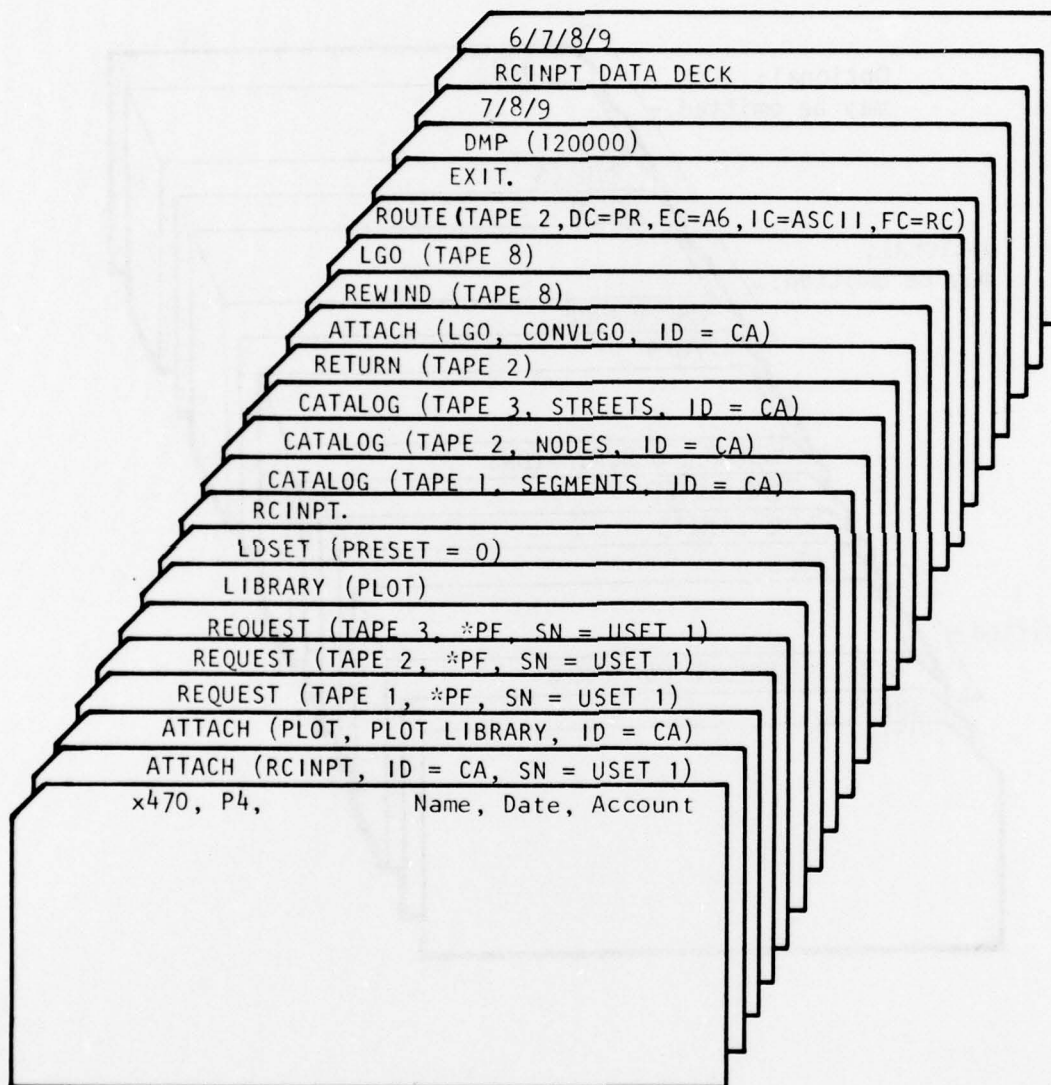


Figure B-11. Deck Setup for RCINPT Run

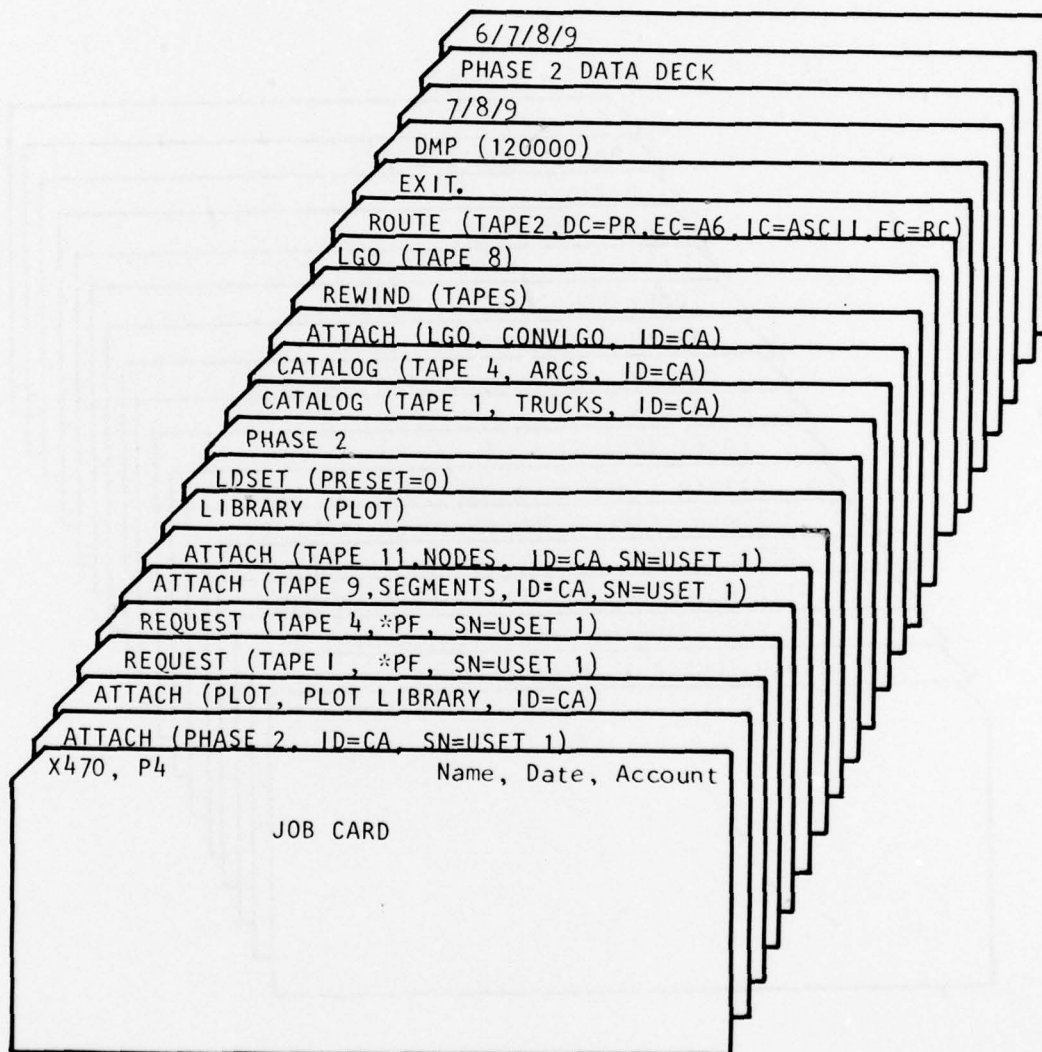


Figure B-12. Deck Setup for PHASE2 Run

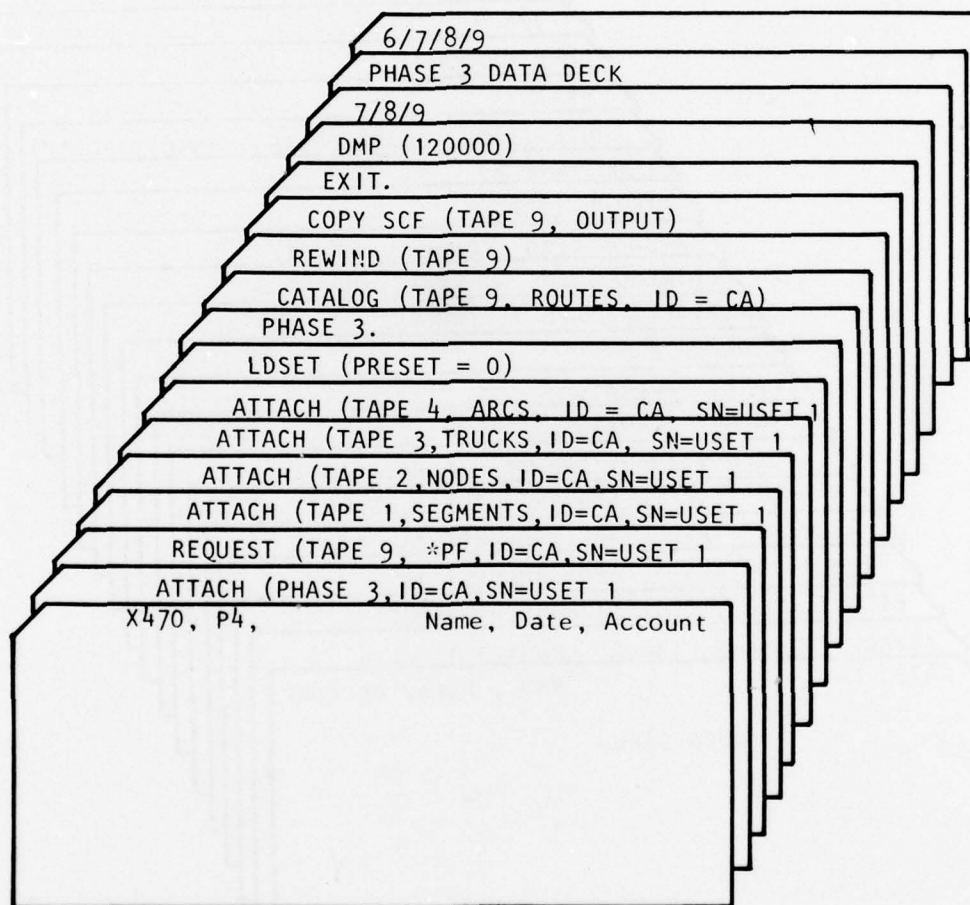


Figure B-13. Deck Setup for PHASE3 Run

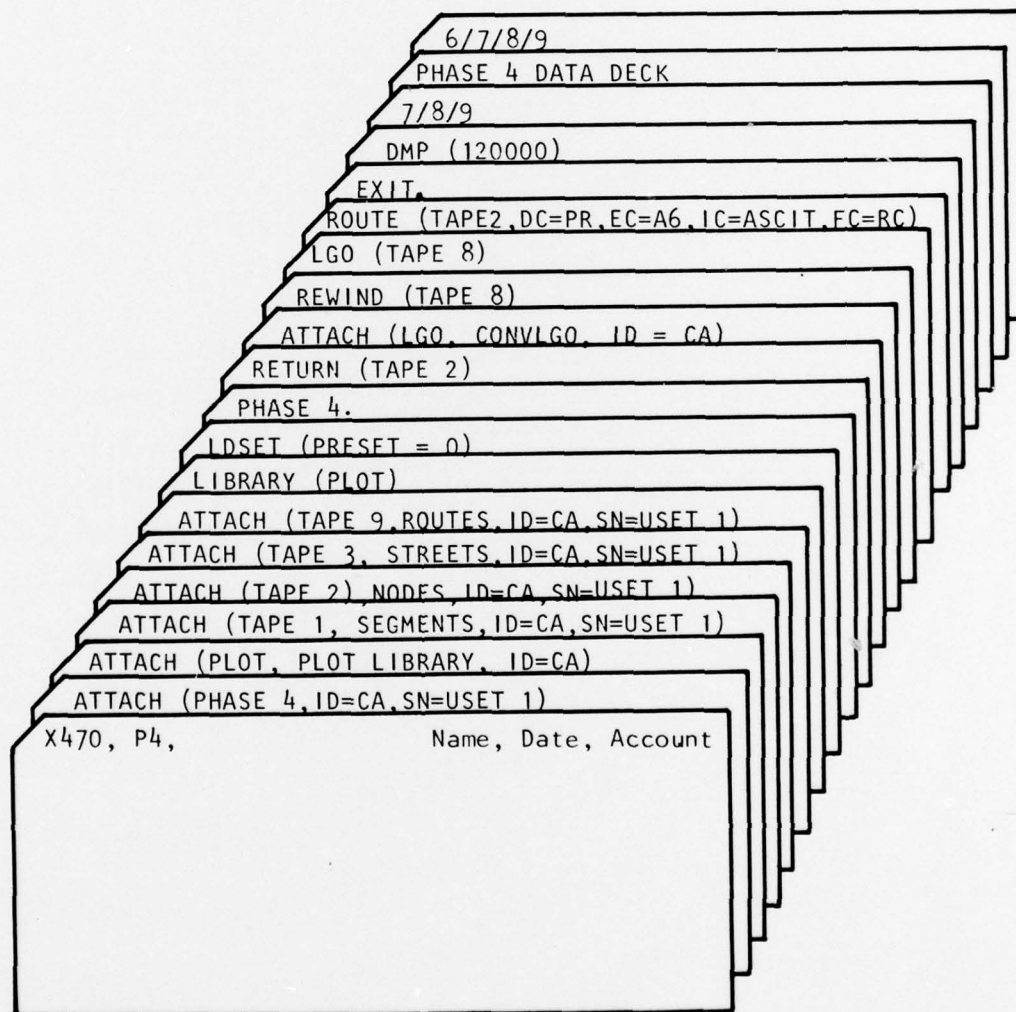


Figure B-14. Deck Setup for PHASE4 Run

## APPENDIX C

### DATA REQUIREMENTS

The user must obtain a street map (or maps) that shows:

1. house or refuse pick-up locations,
2. collection vehicle garage,
3. refuse landfill,
4. streets connecting the housing areas with each other and with the garage and landfill, and
5. street names.

The map scale should be between 200 and 800 feet per inch for housing area maps. If some maps are of noncontiguous regions, a map must be provided which shows streets connecting these areas. This map may have a scale of up to 2 miles per inch.

The following information must be appended to (or provided with) the map:

6. speed limits on each street,
7. either the number of families per house (count single people as 0.5 family) or the quantity of refuse at each pick-up location,
8. arrows indicating the direction of travel on one-way streets,
9. map scale in feet per inch, and
10. deviation from average of neighborhoods known to produce at least 25 percent more or less refuse than average.

As an example of item 10, suppose a mobile home area were known to produce 30 percent less refuse per family than the overall base average; in this case, the area of the map would be circled and marked either 0.7 or -30 percent.

The following information will also be needed:

11. whether one or both sides of the street are to be serviced on one pass (if this varies from street to street, state the more common situation and mark exceptions on the map),

12. average speed of the collection vehicle during refuse collection (exclude the time the vehicle is stopped from the speed estimate),
13. average stop time per house or pickup location, in seconds,
14. average unloading time at the refuse dump,
15. vehicle capacities and number of vehicles of each capacity,
16. maximum speed the collection vehicles can attain if less than 55 mph,
17. either maximum number of families serviced on one trip by each size of collection vehicle (obtain this number from the present routes), or refuse quantity per family per collection in cubic yards, and
18. time restrictions, including maximum work time per day (excluding lunch time), time allowed for lunch, and range of permissible starting and lunch times.

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HQ USAF/RDPS	1	HQ AFSC/DLCAM	1
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HQ USAF/PREVP	1	HQ AAC/DEV	1
HQ ADCOM/DEEV	1	HQ MAC/DEEE	1
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HQ AFLC/DEPV	1	HQ PACAF/DEMU	2
HQ AFLC/DEMU	1	HQ SAC/DEVQ	1
HQ AFSC/DE	1	HQ SAC/DEPA	2
HQ AFSC/SD	1	AFRPL/Library	1
HQ TAC/DEEV	1	ADTC/CSV	1
HQ TAC/DE	1	ADTC/DLODL (Tech Library)	1
HQ USAFE/DEPV	1	HQ USAFSS/DEMM	1
AFISC/SES	1	HQ USAFSS/DEE	1
AFRES/DEEE	1	DDC/TCA	2
HQ USAFA/DEV	1	ARPA	1
HQ USAFA/Library	1	AFOSR/Life Sciences	1
AUL	1	Defense Research & Engrg/AD(E&LS)	1
AU/LDG	1	OASD/(I&L)ES	1
AFML/DO (Library)	1	USAFSAM/EDE	1
OEHL/CC	1	USA Environ Hygn Agency/ENGMC-RD	1
USA WW Exp Station	1	Dir, USA Eng R&D Lab/MERDC	1
NCEL, Code 25111	1	USA CERL	1
Chief of R&D	1	Technology Transfer Staff(EPA)	1
Naval Ship R&D Ctr (Code 3021)	1	National Science Foundation	1
Office of Research & Dev(EPA)	1	3800 ABW/DEE	1
Commander, USA Med Bioengrg	1	AFIT/DEM	1
R&D Lab	2	USAF Rgn Civ Engrg (ER)	1
USAF Rgn Civ Engrg (WR)	1	USAF Rgn Civ Engr (CR)	1
Technical Applications Ctr (UNW)	1	USAFSO/DEE	1
Det 1 ADTC/CC	1	Det 1 ADTC/EC	1
Det 1 ADTC/PRT	1	Det 1 ADTC/ECW(Capt Olfenbittel)	1
AFCEC/DEV	2	Det 1 ADTC/EC (Maj Frein)	1
AFCEC/DEE	2	Det 1 ADTC/ECW (Capt McNutt)	1
Civil Eng Research Facility	1		
(Mr. Harold Iuzzolino)			
AFWL/SUL (Tech Library)	1		